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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 226.

A. C. TRUE, Director.

IRRIGATION EXPERIMENTS AND INVESTIGATIONS IN WESTERN OREGON.

BY

A. P. STOVER,
In Charge of Irrigation Work in Oregon.

PREPARED UNDER THE DIRECTION OF

SAMUEL FORTIER,
Chief of Irrigation Investigations.

WASHINGTON:
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OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Director.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., March 7, 1910.

Sir: I have the honor to transmit herewith a report of experiments in irrigation made by this Office in the Willamette Valley, Oregon. The experiments were made by A. P. Stover, under the direction of Samuel Fortier, chief of irrigation investigations, and have been in progress for some years, the results for the year 1907 being published as Circular 78 of this Office.

The Willamette Valley is peculiar in that it has a very heavy annual rainfall, but a very light summer rainfall, making the midsummer the season when crops do not grow. This valley has been settled for half a century and has been devoted chiefly to wheat growing, for which the climate is admirably adapted, but the long-continued growing of this one crop has brought the land into such condition that profitable crops of wheat are no longer produced, making a change necessary. But the growing season of the other crops extends through the summer drought, making irrigation necessary to their growth. The results reported by Mr. Stover show clearly both the necessity for irrigation and its feasibility. It is recommended that the report be published as Bulletin 226 of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION EXPERIMENTS AND INVESTIGATIONS IN WESTERN OREGON.

INTRODUCTION.

The investigations dealt with in this report were undertaken for the purpose of determining the value of irrigation for increasing and insuring the productiveness of the agricultural lands of the Willamette Valley and other similar valleys of western Oregon.

Climatic conditions in this region for the greater part of the year are typically humid. During the summer months from June to September, however, there is practically no rainfall and almost truly arid conditions exist. Under the agricultural practice of the past this condition has been beneficial rather than otherwise. Extremely mild winters, early moist springs, and dry summers were ideal for the production of grain, which for more than fifty years has been the predominant industry of the region. No thought was given to the value of irrigation during the dry period because it was unnecessary. Grain was a remunerative crop, and every farm was given over to its production to the exclusion of all other crops. Fertile as were these soils in the beginning—and they were fertile or they could not have withstood the abuse they have received—they could stand the constant production of grain only so long and then they began to deteriorate in productiveness, slowly at first but rapidly in later years. Land that once yielded 50 and 60 bushels of wheat per acre now produces in many cases only 10 or 12 bushels per acre, and much of the land can no longer be made to produce at all. Raising wheat on a basis of 12 bushels per acre is not profitable, and as a result grain growing as an industry is being abandoned, and agriculture is being forced to undergo a radical change.

Diversified farming is taking the place of the one time single-crop system. In the production of the new crops new conditions are encountered. What were ideal conditions in the old grain-growing days in the matter of dry summers are far from ideal for the production of these other crops. Grain was ripe and ready for harvest before the dry weather of the summer period could damage the crop, but the crops now being raised—forage, root crops, vegetables, hops, and fruits, the growth of which extends well into and through the dry season—suffer from lack of moisture at the very time they should be making their best growth.

Up to the present time this condition has been met, or more properly evaded, by seeking out favored locations along the river and creek bottoms and other sections where the soil was naturally moist, and bringing these into cultivation to the new crops. Practically nothing is being done, however, with the vast area of grain land that each year is growing less productive, except that in a few of the more favored localities vetch and clover have been introduced and a partial system of crop rotation established. Such, therefore, is the agricultural problem confronting the Willamette Valley and other valleys of western Oregon.

To aid in the solution of this problem, the Office of Experiment Stations was requested in 1906 by the Portland Board of Trade to undertake an investigation of conditions in the Willamette Valley to determine the value and feasibility of irrigation as a means of furthering intensive agricultural development in the affected region. The investigations were begun in 1907 and have been continued through the seasons of 1908 and 1909. Two lines of investigation have been followed during this period: (1) The collection of information bearing upon the feasibility of irrigation in the region being studied, and including physical data relative to climatic condition, topography, water supply, soil and crop conditions. (2) The irrigation of various crops under actual field conditions to determine the value of irrigation in increasing yields, the best methods of preparing land and irrigating it, the proper time of application, and the various other practical questions that require solution in order to properly solve the main problem.

While the investigations have been confined largely to the Willamette Valley, and the experimental work entirely so, it was early recognized that the same conditions existed in the two other valleys of western Oregon, the Umpqua and the Rogue River valleys, and that these sections should be reported upon also. A study, therefore, has been made of conditions in these other valleys and the facts gathered will be presented, thus making this report one dealing with conditions in western Oregon in general rather than in the Willamette Valley alone.

PHYSICAL CHARACTERISTICS OF THE WILLAMETTE VALLEY.

LOCATION AND SIZE.

The Willamette Valley lies in the western part of Oregon, between the high Cascade Mountains on the east and the Coast Range on the west. Its southern boundary is the summit of the Calapooias, a spur range of the Cascades, and its northern boundary the Columbia River. The length of the valley north and south is approximately 150 miles, and its width from summit to summit varies from 50 to 75 miles. Including its mountainous areas, the approximate area

within the Willamette watershed is 8,000,000 acres. Of this considerably over one-half is timbered, mountainous area, the valley and foothill land proper approximating 3,000,000 acres.

STREAMS AND STREAM FLOW.

The dominant physical feature of the valley is its stream system. The Willamette River rises in the southeastern corner of the watershed in the junction of the Calapooias with the high Cascades. Flowing northerly it follows the trough of the valley and empties into the Columbia at the northern extremity of the valley. From the Cascade Range on the east many tributaries make their way toward the trunk stream. Among these are several of the larger streams of the State, such as the Middle Fork, the McKenzie, the Santiam, the Molalla, and the Clackamas. There are a number of tributaries from the Coast Range on the west, but the flow of these is neither so large nor so constant as that which comes from the high watershed of the Cascades. Among the principal streams entering the valley from the west are the Coast Fork, Marys River, Luckiamute, Yamhill, and Tualatin rivers. The discharge of some of these streams during 1906, 1907, and 1908 is given in the following table:

Discharge of Willamette River and its principal tributaries, 1906–1908.[a]

Name of stream and place and time of measurement.	Drainage area.	Discharge.				Run-off.	
		Maximum.	Minimum.	Mean.	Total.	Per square mile.	Depth.
	Square miles.	*Cubic feet per sec.*	*Cubic feet per sec.*	*Cubic feet per sec.*	*Acre-feet.*	*Cubic feet per sec.*	*Inches.*
Willamette River, Albany:							
1906	4,860	52,800	2,810	12,600	9,060,000	2.59	34.93
1907	....	182,000	2,580	16,600	11,900,000	3.41	45.80
1908	....	51,900	2,760	10,400	7,590,000	2.15	29.29
Middle Fork, Jasper:							
1906	1,450	16,400	800	4,020	2,900,000	2.77	37.49
1907	....	93,500	530	5,180	3,690,000	3.57	47.73
1908	....	19,500	880	3,370	2,450,000	2.32	31.62
Coast Fork, Goshen:							
1906	690	15,000	68	1,580	1,130,000	2.28	30.80
1907	....	27,700	93	2,160	1,550,000	3.13	42.08
1908	....	8,030	36	1,310	946,000	1.89	25.73
McKenzie, Springfield:							
1906	960	17,400	1,630	4,650	3,350,000	4.84	65.89
1907	....	37,900	1,630	5,450	3,910,000	5.67	76.34
1908	....	19,200	1,820	4,160	3,020,000	4.34	59.02
North Fork Santiam, Mehama, 1906	740	36,200	700	3,930	2,830,000	5.31	71.67
South Fork Santiam, Waterloo, 1906	640	36,900	192	3,510	2,520,000	5.18	73.78
Molalla, Molalla:							
1906	220	7,120	60	913	656,000	4.15	55.93
1907	....	9,800	....	1,010	721,000	4.58	61.44
1908	....	8,550	....	816	592,000	3.71	50.49
Clackamas, Barton:							
1906	800	25,100	818	3,730	2,690,000	4.66	62.91
1907	....	42,000	600	4,140	2,960,000	5.17	69.40
1908	....	32,500	600	3,050	2,210,000	3.81	51.89
Luckiamute, Suver:							
1906	....	7,450	37	1,090	784,000	....	....
1907	....	9,450	36	1,040	746,000	....	....
1908	....	8,050	44	768	558,000	....	....

[a] U. S. Geol. Survey, Water Supply and Irrig. Papers Nos. 214 and 252.

Owing to the nature of the precipitation the streams have their heaviest discharge during the winter and spring months. As the summer flow of the streams has an important bearing upon the feasibility of irrigation, the relation of the summer flow to the total yearly flow for the years 1906, 1907, and 1908 is given in the following table:

Yearly discharge and summer discharge of streams in Willamette Valley, 1906–1908.

Name of stream and place of measurement.	Year.	Yearly discharge.	Discharge during July, August, and September.	
		Acre-feet.	*Acre-feet.*	*Per cent.*
Willamette, Albany	1906	9,060,000	747,000	8
Do	1907	11,900,000	658,000	5
Do	1908	7,590,000	770,000	10
Middle Fork	1906	2,900,000	215,600	7
Do	1907	3,690,000	134,500	4
Do	1908	2,450,000	253,500	10
Coast Fork	1906	1,130,000	34,550	3
Do	1907	1,550,000	27,970	2
Do	1908	946,000	43,390	4
McKenzie	1906	3,350,000	437,000	13
Do	1907	3,910,000	424,000	10
Do	1908	3,020,000	434,000	14
North Fork Santiam	1906	2,830,000	191,600	7
South Fork Santiam	1906	2,520,000	86,300	3
Molalla	1906	656,000	26,230	4
Do	1907	721,000	18,850	3
Do	1908	592,000	22,260	4
Clackamas	1906	2,690,000	192,300	7
Do	1907	2,960,000	196,500	7
Do	1908	2,210,000	203,500	9
Luckiamute	1906	784,000	22,060	3
Do	1907	746,000	12,180	2
Do	1908	558,000	16,360	3

TOPOGRAPHY.

The mountainous portion of the Willamette drainage area comprises 5,000,000 acres or more. In the Cascades there are a number of high mountain peaks, among the most noted of which are Mount Hood, Mount Jefferson, and the Three Sisters. The elevation of the summit of the Cascades varies from 7,000 to 9,000 feet. The mountain slopes are very heavily timbered, affording excellent protection to the water supply coming from that side of the valley. The mountainous area merges into the valley area proper through a zone of low, rolling foothill country that is more or less wooded. The floor of the valley is a series of smooth, level areas known as "prairies" or "plains," whose slope is extremely uniform and ranges from 4 to 15 feet per mile. The north end of the valley is more or less broken and cut into lesser valleys by a series of low, rolling hills and by the foothills spreading over a wider area. In the south end of the valley—from Eugene as far north as Salem—the floor of the valley, although somewhat cut up by the various streams, is extremely even in slope, and large bodies of level prairie land are to be found. Along the streams are bottom lands, usually more or less wooded and subject to overflow in the winter time.

SOILS.

The soils of the valley are largely of basaltic origin. They are quite variable in character, but in general may be classified as follows:

Foothill soils.—These are confined to the higher rolling foothill sections. As a rule they have better natural drainage and are more friable than the soils of the prairies. In sections of the valley the hill lands are a sandy loam merging into a gravelly loam, not always of great depth, but usually deep enough for successful cultivation. In the foothills there is also a considerable area of what is locally called "shot land," because many of the soil particles have the form of small pellets resembling shot. In general the rolling hill land may be considered the best for fruit culture, because of its better condition, drainage, and freedom from frost.

Valley or prairie soils.—The soils of the floor of the valley are alluvial in character and vary greatly in texture from coarse gravelly loams, such as are found in parts of Marion and Lane counties, to the fine clay soils of Linn and Benton counties. The greater part of these soils, especially in the south end of the valley, may be classed as clay loams. These, as a rule, have a clay subsoil, but in many sections the subsoil is gravel. In the sections where the gravelly subsoil does not exist and where the surface drainage is poor, the heavy winter rainfall saturates the soil and hinders early cultivation in the spring. It is in such sections as these that the so-called "white lands," which are so unproductive, appear. They occur in isolated seams and patches throughout the darker colored loams, and are always found in low places and depressions where the drainage is poor and where during the winter season and far into the spring the land is under water. Except, perhaps, in the amount of humus contained, they have nearly the same chemical nature as the other clay loams that surround them, but they are compact and run together; that is, more or less puddled.

The soils of the valley which are likely to be most productive under irrigation are the gravelly and sandy soils and the friable clay loams of the foothills and prairies, all of which, as a rule, have good natural underdrainage. These lands no longer yield good crops of wheat, and for the most part now lie comparatively idle and unproductive. The greater part of this land lies in the south end of the valley in Lane, Linn, Benton, and Marion counties.

Bottom soils.—Soils of this type are found along the river and creek bottoms that are more or less subject to overflow, and are therefore quite limited in extent. They are the richest soils in the valley, being composed of alluvial deposits of basaltic origin mixed with sand and a high percentage of vegetable matter. They are easily cultivated

and are considered the most productive soils of the valley. What are commonly called "beaver dam lands" belong to this type. Except where these soils have an extremely porous subsoil or do not receive natural subirrigation from the higher lands, it is improbable that irrigation will be resorted to, except for some special use, such as market gardening.

Of the three types, the valley or prairie soils, by reason of their greater extent and because of their location and inability to withstand drought, will yield the largest return under irrigation.

CLIMATE.

Although in the same latitude as Montreal, the Willamette Valley, because of its proximity to that part of the Pacific coast which is washed by the warm Japan current, has an extremely mild climate. No extremes of either heat or cold are experienced. Summer temperatures rarely exceed 100° F., and then only for a very few days during the season, from 85° to 90° being the usual maximum temperature for summer. The nights are always cool. In winter the temperature is sometimes as low as 10°, but never for any considerable period. Periods of mild temperatures are frequent, and throughout most winters grass remains green in the meadows and pastures. The crop season proper extends from April 1 to about October 15, a period of nearly seven months. Cultivation can be begun as early as February 15 some seasons, but usually the farming season opens in March. Annuals, such as grain, planted at this time, usually mature successfully before the summer dry period, unless a drought occurs in May or early in June. Other crops whose growth extends into the dry summer months, unless favorably located on land that is naturally retentive of moisture, suffer in the dry months of July, August, and September.

The rainfall in the Willamette Valley is considerably greater than in the other valleys of western Oregon, but the increase is confined to the winter months when the rainfall is very heavy. During the summer months the rainfall is not greatly different from that in the Umpqua and Rogue River valleys. In the following table the normal rainfall as determined by the United States Weather Bureau at eight different points in the Willamette Valley is given. The several stations are all located in the bottom of the valley and the records given represent the precipitation in the section devoted to agriculture.

Normal rainfall at points in the Willamette Valley.[a]

Station.	Length of record (years).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
		Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*In.*	*In.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
Eugene	16	5.44	4.87	4.99	2.93	2.67	1.36	0.48	0.76	1.90	2.87	5.45	6.25	39.98
Albany	29	7.00	5.64	4.52	3.16	2.49	1.54	.50	.51	1.87	3.12	5.62	7.91	43.88
Corvallis	18	6.33	5.81	4.98	3.00	2.21	1.26	.26	.41	1.51	2.90	7.57	7.11	43.35
Monroe	12	6.95	7.53	5.94	2.69	2.06	1.19	.29	.64	1.65	3.14	9.08	8.15	49.31
Salem	17	5.42	4.40	4.51	3.08	2.61	1.29	.39	.46	1.60	3.08	6.56	5.91	39.31
Mount Angel	22	6.58	5.08	5.18	3.80	2.92	2.04	.64	.49	2.09	3.66	7.18	6.97	46.63
McMinnville	20	7.19	5.40	4.94	3.25	2.03	1.65	.40	.56	2.06	3.33	8.39	7.93	47.13
Portland	60	6.32	4.96	4.74	2.94	2.38	1.77	.75	.58	1.69	3.11	6.00	7.21	42.45
Average	....	6.40	5.46	4.98	3.11	2.42	1.51	.46	.55	1.80	3.15	6.98	7.18	44.00

[a] Figures furnished by United States Weather Bureau.

Although the records indicate that the south end of the valley receives slightly less rainfall than the north end, the variation is so small and so irregular as to cause practically no difference in agricultural conditions. With different years the rainfall varies quite widely—from 25 inches at Salem, in 1903, to 66 inches at Monroe, in 1902. The greatest variation, however, occurs with the different seasons of the year, over three-fourths of the yearly rainfall occurring during the winter season, from November to March, while during the summer period, from June to September, inclusive, very little rainfall occurs, the average during this period being less than 10 per cent of the yearly rainfall.

PHYSICAL CHARACTERISTICS OF THE UMPQUA VALLEY.

LOCATION AND SIZE.

The Umpqua Valley lies just south of the Willamette Valley and extends from the Calapooia Mountains on the north to the Canyon Mountains, which separate it from the Rogue River Valley on the south. The eastern boundary of the drainage system is the summit of the Cascade Range; the western boundary, the Pacific Ocean. The drainage basin extends north and south 70 miles and east and west 100 miles. It contains within its watershed approximately 3,000,000 acres of land.

STREAMS AND STREAM FLOW.

The Umpqua River, which drains the Umpqua basin, has its origin in the high Cascades, from which its two main tributaries, the North and South forks, flow. These two tributaries flow westward from their sources and join near the town of Roseburg. From that point the main stream flows in a northwesterly direction and empties directly into the ocean. There are numerous minor tributaries entering the main stream from both the north and the south. The prin-

cipal flow, however, comes from the North Fork and the South Fork. The discharge of the main stream and these two forks during 1906, 1907, and 1908 is given in the following table:

Discharge of Umpqua River and its tributaries, 1906–1908.[a]

Name of stream and place and time of measurement.	Drainage area.	Discharge.				Run-off.	
		Maximum.	Minimum.	Mean.	Total.	Per square mile.	Depth.
	Square miles.	*Cu. ft. per second.*	*Cu. ft. per second.*	*Cu. ft. per second.*	*Acre-feet.*	*Cu. ft. per second.*	*Inches.*
Umpqua River, Elkton: 1906		61,400	1,290	7,700	5,540,000		
North Fork Umpqua, Oakcreek:							
1906	1,000	26,800	952	3,930	2,830,000	3.93	53.12
1907		58,600	1,060	5,090	3,640,000	5.09	68.32
South Fork Umpqua, Brockway:							
1906	1,800	46,400	171	2,380	1,700,000	1.50	17.77
1907		68,800	182	3,790	2,700,000	2.11	28.29
1908		13,000	160	1,940	1,400,000	1.08	14.62

[a] U. S. Geol. Survey Water-Supply and Irrig. Papers Nos. 214 and 252.

Like the Willamette Valley streams, the streams of the Umpqua Valley have their heaviest discharge in the winter and spring months and their minimum discharge occurs during the dry period, when the demand for irrigation will be greatest. A comparison of the total annual flow of these streams with their flow during the summer season is given in the following table:

Yearly discharge and summer discharge of streams in Umpqua Valley, 1906–1908.

Name of stream and place of measurement.	Year.	Yearly discharge.	Discharge during July, August, and September.	
		Acre-feet.	*Acre-feet.*	*Per cent.*
Umpqua, Elkton	1906	5,540,000	296,000	5
North Fork Umpqua, Oakcreek	1906	2,830,000	232,000	8
Do	1907	3,640,000	241,800	7
South Fork Umpqua, Brockway	1906	1,700,000	53,900	3
Do	1907	2,700,000	44,700	2
Do	1908	1,400,000	46,880	3

TOPOGRAPHY.

The Umpqua Valley differs from the Willamette Valley in that it is not a true valley, but rather a succession of small valleys scattered at intervals along the main streams and separated from one another by ranges of hills. The arable area of these small valleys varies in size from a few hundred acres to 15,000 acres and more. Their elevation varies from tide water up to 1,000 feet above sea level. The larger and more important valleys lie near the junction of the North and South forks, in the vicinity of Roseburg. Here is found Garden Valley, which surrounds Roseburg; Coles Valley, lying 8 or 10 miles

lower down on the main stream; Sutherlin Valley, in the vicinity of Oakland; with Lookingglass, Happy, Myrtle Creek, and other minor valleys located in the same section. The elevation of these main agricultural areas varies from 400 to 600 feet above sea level. The mountainous areas to the eastward and also in the coast region are heavily timbered with fir, spruce, pine, and cedar, while the hills and bench lands in the agricultural section are covered with maple, oak, and scrub brush. The bottom land in the larger valleys is level and for the most part has been in cultivation for many years.

SOILS.

The valley soils are sedimentary deposits brought down from the hills, and for the most part are of a sandy nature and yield readily to cultivation. The foothill soils are lighter in texture, somewhat gravelly, and are reddish brown in color, due to the iron oxid they contain. The bottom soils along the streams are rich in vegetable matter, easy to cultivate, and very fertile.

CLIMATE.

In general the climatic conditions are much the same as in the Willamette Valley. The rainfall is somewhat less in the agricultural section, but its distribution is characterized by the same unevenness. The thermometer will register more than 100° F. in the summer occasionally, and in the winter will drop to 12° or 15°, but these may be considered as extreme temperatures, the climate being very moderate during all seasons of the year.

The annual rainfall of the valley section, taking Roseburg as the center, is approximately 35 inches. Eighty-six per cent of this rainfall occurs during the period from October 1 to April 30, leaving but 14 per cent, or 4.91 inches, for the five-month crop-growing season of May, June, July, August, and September, while the average rainfall during the months of June, July, and August is only 1.81 inches. For reference in the discussion to follow, the normal monthly and normal annual rainfall at Roseburg for 32 years, as given in the records of the United States Weather Bureau, are as follows: January, 5.64; February, 4.80; March, 3.83; April, 2.36; May, 2; June, 1.12; July, 0.35; August, 0.34; September, 1.10; October, 2.66; November, 4.33; December, 6.14; annual, 34.67 inches.

PHYSICAL CHARACTERISTICS OF THE ROGUE RIVER VALLEY.

LOCATION AND SIZE.

Rogue River Valley consists of two main valleys, the upper one surrounding the town of Medford and including most of Jackson County; the lower one surrounding the town of Grants Pass and

including most of Josephine County. It joins the Umpqua Valley on the north and extends southward to the summit of the Siskiyou Mountains, which follow in a general way the boundary line between Oregon and California. The eastern boundary of the drainage basin is the Cascade Range, the western the Pacific Ocean. The watershed of Rogue River contains approximately 3,000,000 acres of land, nine-tenths of which is rough mountainous territory, unfit for cultivation.

STREAMS AND STREAM FLOW.

Rogue River rises in the western slopes of the Cascade Range, between Crater Lake and Mount McLoughlin. Flowing thence westward, it passes in turn through the upper and lower valleys and then following a rugged, precipitous channel for a distance of 85 miles, it empties directly into the Pacific Ocean at a point about 35 miles north of the Oregon-California boundary line. Many tributaries join the main stream from both the north and south sides of the drainage area throughout its course. The more important of these, named in order as they enter the river on its way to the ocean, are: Big Butte Creek, Little Butte Creek, Bear Creek, Evans Creek, Applegate River, and Illinois River. All of these enter the main stream from the south, the greater part of the drainage area being on that side. With the exception of the Illinois River, which enters the main stream near its mouth and drains a rough, broken country, all of these tributaries have important bearing on the irrigation development of the two main valleys.

Only in recent years has any extended observation of the flow of Rogue River and its tributaries been made. The discharge of the main river is measured at Tolo, where it leaves the upper valley. Such data as is available, however, appears in the following table:

Discharge of Rogue River and its tributaries, 1907 and 1908.[a]

Name of stream and place and time of measurement.	Drainage area.	Discharge.				Run-off.	
		Maximum.	Minimum.	Mean.	Total.	Per square mile.	Depth.
	Square miles.	*Cu. ft. per second.*	*Cu. ft. per second.*	*Cu. ft. per second.*	*Acre-feet.*	*Cu. ft. per second.*	*Inches.*
Rogue River, Tolo:							
1907	2,020	48,300	1,190	4,450	3,180,000	2.20	29.54
1908	....	12,900	1,400	2,970	2,160,000	1.47	20.01
Little Butte Creek, Eagle Point, 1908	309	1,730	33	231	168,000	.75	10.17
Bear Creek, Talent, 1908	226	500	2	72.1	52,300	.32	4.33
Applegate River, Murphy, 1908	620	2,690	25	591	428,000	.95	12.93

[a] U. S. Geol. Survey Water Supply and Irrig. Papers Nos. 214 and 252.

Yearly discharge and summer discharge of streams in Rogue River Valley, 1907 and 1908.

Name of stream and place of measurement.	Year.	Yearly discharge.	Discharge during July, August, and September.	
		Acre-feet.	*Acre-feet.*	*Per cent.*
Rogue River, Tolo	1907	3,180,000	336,700	10
Do	1908	2,160,000	318,700	10
Little Butte Creek, Eagle Point	1908	168,000	8,180	5
Bear Creek, Talent	1908	52,300	2,121	4
Applegate River, Murphy	1908	428,000	22,680	5

TOPOGRAPHY.

Though the drainage area of Rogue River contains approximately 3,000,000 acres of land, but a small fraction of this can be classed as agricultural or tillable land. The entire area is essentially a broken, mountainous region similar to the Umpqua Basin, with the agricultural land lying in small valleys more or less isolated from one another by intervening ranges of mountains and hills. Outside of the two main valleys the level lands are confined to small areas found along the main streams and creeks. In the upper valley, extending from Rogue River south as far as Ashland, there are between 100,000 and 150,000 acres in one body divided about equally between valley and rolling foothill land. The lower valleys contain not to exceed 100,000 acres, and only about one-fourth of this is valley land proper, the remainder being hill land, more or less rolling and rough. The mountainous areas are heavily timbered with fir, pine, and other commercial varieties of timber, while the lower elevations surrounding the valleys, are covered with a growth of scrub pine, oak, laurel, and manzanita.

SOILS.

In no other part of the State is found such a wide variety of soils as occurs in the Rogue River Valley. The soils in the lower valley fall naturally in three classes, viz: (1) The alluvial soils of the river and creek bottoms; (2) the red foothill lands found in the Applegate, Fruitdale, and Evans Creek districts; and (3) the granite soils which cover the greater part of the foothill section on the north side of the valley. These three types of soil are not confined entirely to the localities mentioned, but are found more or less intermingled over the entire cultivable area, giving an extremely varied soil condition. Soils of the first two classes are more productive than the granite soils, because they contain a much higher percentage of organic matter and, being finer textured, are more retentive of moisture. The granite soils when put under irrigation and planted to leguminous crops, can be brought to a very productive condition and are found to be well adapted to the production of early fruits and vegetables.

The soils in the upper valley are, if anything, more variable than in the lower valley. No less than five types of soil occur in this region, all intermingled to such an extent that it would be difficult to select a 40-acre tract in this valley on which could not be found representatives of at least two of these types of soil. In certain localities, however, each of these different types predominates. In the south end of the valley near Ashland, the soil is largely a decomposed granite similar to that found in the lower valley. Along the bottoms of Bear Creek, running through the center of the valley, the soil is a rich alluvial deposit. On the east side of Bear Creek are found the "sticky" soils, which are heavy clay loams rich in organic matter. On the west side of Bear Creek black gravelly loams are found. In the north end of the valley on the "desert" are found the light gravelly soils, which have been brought down from the mountains by glacial action. A considerable part of this area is underlaid with a thin sheet of coarse cement gravel, underneath which is found both porous gravel and loam to a great depth. Around the foothills on both sides of the valley are found the typical red and black foothill soils, which are deep, well drained, and warm. All of these types are very productive, especially when irrigated. Crops are being raised on most of these soils without irrigation, but the production in most cases is not what it should be nor what it will be when adequate facilities for irrigating the land are provided.

CLIMATE.

Temperature conditions in Rogue River Valley are not greatly different from those in the Willamette and Umpqua valleys. The winters, with 12° to 15° F. as rare minimum temperatures, are extremely mild. In summer the temperature rises to 104° and 106° F. occasionally, but this heat is not oppressive, and such temperatures usually last only a few days at a time, being then tempered by breezes from the ocean. The last killing frosts in the spring occur usually in April, while the first killing frost in the fall occurs usually about November 1.

The annual precipitation in the agricultural section, taking Ashland, Jacksonville, and Grants Pass as centers of record, varies from 20 to 25 inches in the upper valley to 32 inches in the lower valley. The distribution of this rainfall is extremely uneven, the greater part occurring during the winter and spring seasons. The dry period comes on usually about June 1 and lasts into October. The average precipitation during the four-month period is but 2.5 inches. The normal rainfall at the three United States Weather Bureau stations in the valley is given in the table on page 19.

Normal rainfall at points in the Rogue River Valley.[a]

Station.	Length of record (years).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
		Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*In.*	*In.*	*In.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
Ashland..........	30	2.90	2.37	2.13	1.45	1.65	1.05	0.46	0.38	0.75	1.43	2.31	3.30	20.18
Jacksonville.....	21	4.62	4.14	2.79	1.28	1.79	1.02	.19	.35	.91	1.77	3.81	4.67	27.34
Grants Pass......	20	5.60	4.97	3.89	1.66	1.84	.94	.10	.33	.89	2.07	4.35	5.56	32.20
Average...	....	4.37	3.83	2.94	1.46	1.76	1.00	.25	.35	.85	1.76	3.49	4.51	26.57

[a] Figures furnished by United States Weather Bureau.

THE NEED OF IRRIGATION.

Moisture, the sun's heat and light, and soil fertility are the three essentials to successful plant growth. With a deficiency in any one of these factors plants can not maintain a thrifty growth and development. All of the soils in the region under discussion are fertile except as they may have become impoverished by the destructive methods of cultivation employed in the past, but such deficiency as exists in this essential can be easily remedied by constructive methods of cultivation and fertilization. The two other essentials have a most important bearing on the question in hand and require a full discussion in order to determine on the theoretical side whether or not irrigation is needed to improve conditions in the region observed

The need of irrigation in any region, arid or humid, is determined, not by the total amount of rainfall occurring during the year, but by its distribution throughout the year; in other words, by the amount of rainfall occurring in the crop-growing season, May to October, during which period the warmth and light of the sun's rays are most effective. To illustrate graphically how unevenly the rainfall is distributed throughout the year in western Oregon the accompanying diagram (fig. 1) has been prepared. This diagram is based upon all the available records that have been kept by the United States Weather Bureau at the several stations given in the foregoing tables. The records at one of these stations have been kept for sixty years. The shortest period of observation, that at Monroe, in the Willamette Valley, is twelve years. The average upon which the diagram is based may therefore be taken as well established.

It will be seen from figure 1 that from October to March approximately 78 per cent of the yearly rainfall occurs. This is the dormant season during which there is no crop growth. During the period from April to September when there is warm weather and sunshine but 22 per cent of the rainfall of the year occurs. This 22 per cent, however, is not distributed evenly over the summer period, but comes mostly in April and May and in the latter part of September, so that

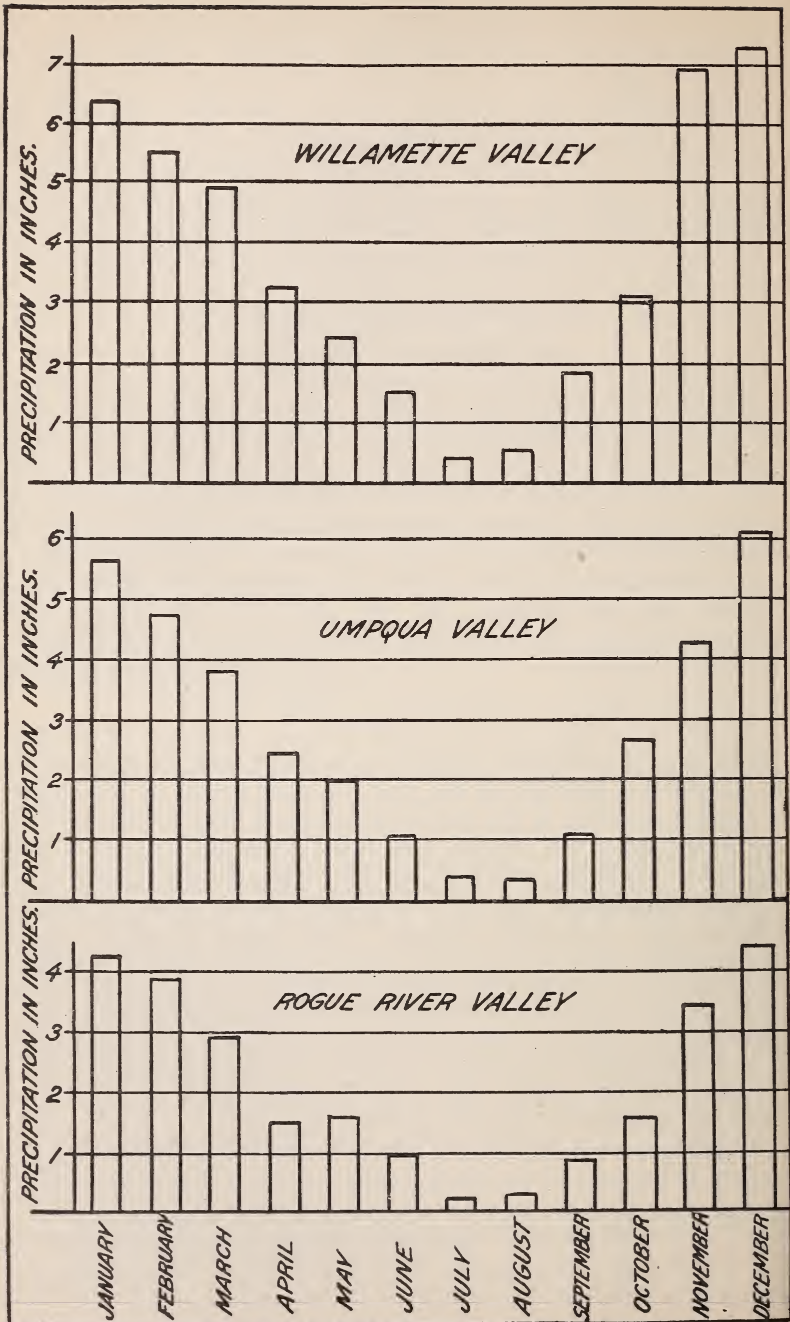

FIG. 1.—Diagram showing normal monthly rainfall in the three valleys of western Oregon.

during the remainder of the crop-growing season there is actually an arid condition existing. The rainfall during June, July, and August—the three best growing months of the year—is but 2.52 inches in the Willamette Valley, 1.81 inches in the Umpqua Valley, and 1.60 inches in the Rogue River Valley, and the majority of the rains occurring in the summer period are little more than showers; although their aggregate makes a considerable showing, they are of little benefit to growing crops, because they do little more than moisten the surface of the soil and do not reach to the roots of most plants.

The season of 1907 in the Willamette Valley illustrates this point very clearly. The total amount of rainfall and its distribution were about normal. The summer rainfall came in three distinct shower periods, the first occurring in the latter part of June and the first part of July, the second occurring about the middle of August, and the third toward the end of August. The character of the rainfall occurring during these three periods at Portland, Albany, Corvallis, and Eugene is shown in the following table:

Shower period in Willamette Valley, summer of 1907.[a]

Date.	Portland.	Albany.	Corvallis.	Eugene.
First period:	*Inches.*	*Inches.*	*Inches.*	*Inches.*
June 28	0.28		0.18	0.03
June 29		0.16		
June 30				.02
July 1	.12			
July 2	1.00			
July 3	.06	.40	.24	.09
July 4		.02		
Total	1.46	.58	.42	.14
Second period:				
August 7	.15	.01	.28	.40
August 8	.07	.62	.21	.55
August 9		.02		.07
August 10	.02			
August 11		.04		
Total	.24	.79	.49	1.02
Third period:				
August 23				
August 24	.69	.12	.44	.45
August 25	.04	.25	.20	
August 26			.02	
Total	.73	.37	.66	.45
Total for season	2.44	1.74	1.57	2.61

[a] U. S. Dept. Agr., Office Expt. Stas. Circ. 78, p. 10.

The late spring rainfall ceased on June 15. Between that time and the beginning of the first shower period on June 28 there were a few isolated showers at different points in the valley, but no general rain. The heaviest shower at any point during this period was 0.09 inch at Portland on June 21. During the first period the heaviest shower occurred at Portland on July 2, when 1 inch of rain fell. The

only other rainfall of value was at Albany on July 3, when 0.40 inch fell. Between the first and second shower periods there was no rainfall anywhere in the valley except on July 14 and 25 at Eugene, when

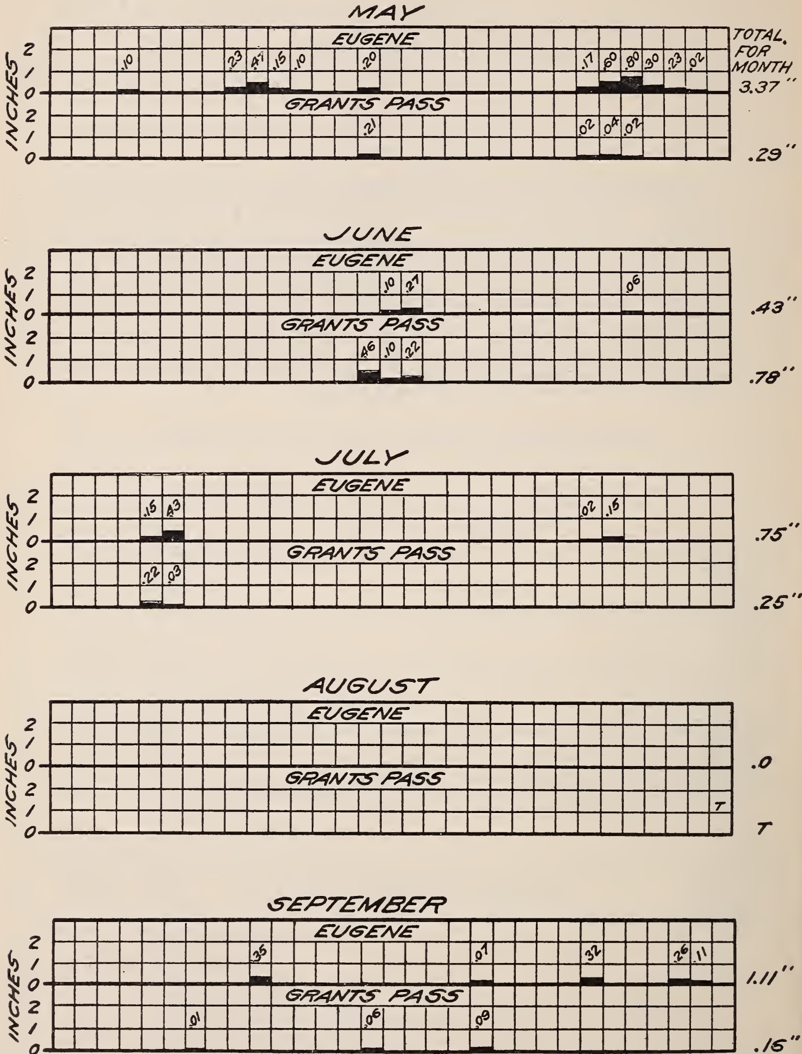

FIG. 2.—Diagram showing distribution and amount of rainfall during the summer months of 1909 at Eugene and Grants Pass.

0.04 inch and 0.05 inch occurred, respectively. These were so small, however, as to be negligible. For a period of thirty-three days, therefore, the valley was without appreciable rainfall. The total

rainfall during the shower period, averaging the four stations, was only 0.63 inch, spread over a portion of five days, about one-eighth inch per day, which was too small an amount to be of any value to crops. Between the second and third shower periods, twelve days, no rain fell, and during the third shower period the amount of precipitation—but little more than 0.55 inch—was so small as to be of little value on lands that had been subject to hot weather for fifty days.

To further illustrate this condition, figure 2 has been prepared. This diagram shows the distribution and amount of rainfall received each day during the months of May, June, July, August, and September, 1909, at Eugene, in the Willamette Valley, and at Grants Pass, in the Rogue River Valley.

Figure 2 shows that for the five-month period (May to September, inclusive) in 1909 the total rainfall at Eugene was 5.66 inches. Of this amount 3.37 inches fell in May, leaving for the remaining period of four months only 2.29 inches of rainfall. From July 26 to September 10, a period of six weeks, not a drop of rain fell. At Grants Pass the same condition in a more aggravated form existed. A rainfall of from 1 to 2 inches scattered over a period of ninety days in light showers of from 0.25 to 0.5 inch does no good to land that is as dry as practically all the valley lands are during July, August, and September. In exceptionally favored localities, on account of natural subirrigation, the soil with the aid of these light showers can be kept in good moisture condition, but these localities, while they form the greater part of the producing area at the present time, are in the aggregate very small indeed when compared with the larger area that is vitally affected by drought.

It is seen, therefore, that although 25 to 45 inches of rain fall annually in this region, it is so unevenly distributed that during the best months of the crop-growing season—June, July, August, and September—practically an arid condition exists, during which the precipitation is almost the same in amount as in the truly arid sections of Idaho, Washington, or Colorado, where irrigation is generally practiced. This is a fact not generally known, and by some would no doubt be considered a pretty broad statement. To substantiate it, the accompanying diagram (fig. 3), based upon records of the United States Weather Bureau, is introduced. This diagram compares on a common scale the rainfall conditions at Eugene and Grants Pass with the rainfall conditions at Sunnyside, Wash., Twin Falls, Idaho, and Denver, Colo., all well-known points in the arid region. The columns in outline show the total annual rainfall. The columns in solid black show the rainfall occurring during June, July, and August, while the dotted columns show the added depth of water which crops receive by irrigation during this same three-months

period in these three arid sections. This diagram brings out the fact clearly that conditions in the valleys of western Oregon during June, July, and August are as arid as those of the truly arid region during the same period.

To show still further how such a deficiency in moisture as occurs in the valleys of western Oregon each year is met under arid conditions, further reference will be made to one particular irrigated section of the Yakima Valley in eastern Washington. Climatic, soil,

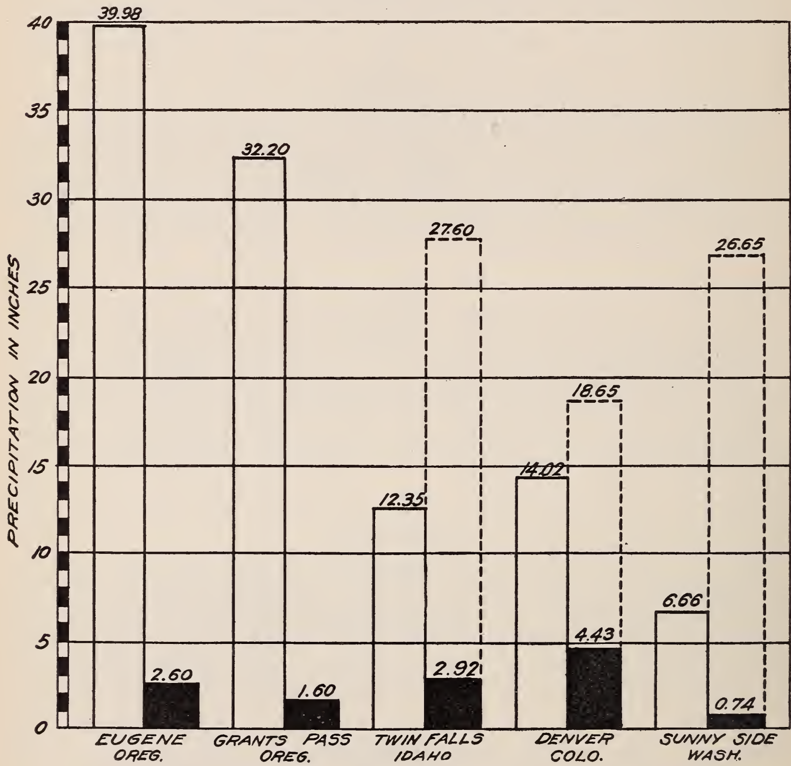

FIG. 3.—Diagram comparing normal annual and normal summer rainfall conditions in western Oregon with conditions during summer period in irrigated sections of Washington, Idaho, and Colorado.

and crop conditions are of course not exactly similar in the two sections, but are sufficiently so for the purpose in hand.

For a number of years the Office of Experiment Stations has kept records of the use of water under the Sunnyside Canal system in the Yakima Valley. In 1905 an accurate record was kept of the water applied under seven laterals of the Sunnyside Canal which supplied water to 4,355 acres of land. The irrigation season in that section in 1905 extended over a period of five months, beginning in May, but

for the sake of comparison with western Oregon conditions on a three-month basis the amount of water applied during July, August, and September only is given in the following table:

Water applied to lands under Sunnyside Canal, Yakima Valley, Washington, 1905.

No. of lateral.	July.	August.	September.	Total water.	Acreage.	Depth applied to land.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acres.*	*Inches.*
39.1	380	358	275	1,013	496.4	24.48
34.1	603	600	315	1,518	1,355.0	13.56
32.3	940	956	573	2,469	1,150.0	25.68
29.1	294	272	104	670	333.0	24.12
19.6	273	200	178	651	275.0	28.32
20.4	231	212	106	549	198.0	33.12
27.1	535	301	381	1,217	547.5	26.64
Total				8,087	4,354.9	22.28

It will be noticed that the lateral supplying the least water delivered upon the land 14 inches in depth, while the lateral supplying the greatest amount delivered 33 inches in depth. For all the laterals the mean amount applied during this three-month period was 22 inches. During the three months the rainfall at Sunnyside amounted to 1.77 inches. In the Willamette Valley during the same three months in 1905 the rainfall averaged 1.58 inches. In the Yakima Valley, therefore, land in crop received during July, August, and September 24 inches of water, while land in crop in the Willamette Valley received only 1.58 inches. This wide variation in the amount of water received by the crops in the two valleys during the three-month summer period is worthy of careful note, and while the two valleys are not exactly comparable, and the amount of water applied under the Sunnyside Canal may have been more than was actually required, the comparison seems to fully warrant the conclusion that could the natural rainfall in the Willamette Valley be supplemented by irrigation, as is done in the Yakima Valley, a far greater and at the same time safer use could be made of the lands that are now doing only partial duty.

As showing what is already being accomplished with irrigation under climatic conditions similar to those existing in the Willamette Valley, brief reference will be made to the Po Valley in Northern Italy,[a] where, notwithstanding the existence of a humid climate, irrigation has been depended upon for centuries to bring about the fullest agricultural production. The upper part of the valley of the Po resembles in many respects the Willamette. On three sides it is surrounded by high mountains—the Alps on the north and east, and the Apennines on the south—from which a network of streams make their way to the Po, the trunk stream of the valley. The valley

[a] U. S. Dept. Agr., Office Expt. Stas. Buls. 144 and 190.

itself consists of a foothill section and a broad level plain, situated in practically the same latitude as the Willamette. The climate of the two valleys is very similar. In the Provinces of Piedmont and Lombardy the temperature varies from zero to 100° F. The crops raised are those of the temperate zone—cereals, hay, vegetables, and fruit. The rainfall varies from 30 to 40 inches, and irrigation is practiced extensively.

The annual rainfall at Milan, the heart of the great irrigated district of Lombardy, averages 40 inches, nearly as much as in the Willamette Valley, while at Turin, the capital of Piedmont, it is 31 inches. The distribution of this rainfall is far more even and more favorable to plant growth than that in the Willamette Valley, as indicated in the accompanying summary.

Distribution of rainfall by seasons at Milan and Turin, Italy, and in the Willamette Valley, Oregon.

Locality.	Annual rainfall.	Winter.	Spring.	Summer.	Autumn.
	Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Milan	40	21.3	23.9	23.9	30.9
Turin	31	14.7	26.3	31.6	27.4
Willamette Valley	44	38.3	16.0	6.4	39.3

The above table shows that for the spring and summer months the rainfall in the Willamette Valley is only about one-half that at Milan. During the driest month of the year more rainfall occurs on the average at Milan than during the whole three months' summer period in the Willamette Valley. In the Province of Piedmont alone, which is a little smaller than the Willamette Valley, over 700,000 acres are under irrigation (1903), twice as much as in the whole State of Oregon, and the canals and laterals built by the Italian Government, to say nothing of those built by private capital, aggregate in this one Province a length of 926 miles. Irrigated land under the Villoresi Canal is valued at $160 to $200 per acre, while unirrigated land sells for $100 per acre. On this point Elwood Mead says:

The conditions under which farmers work in this part of Italy are wholly different from those which prevail in the arid regions of America. In the midst of the Corbetta district farms are being cultivated without irrigation which grow the same crops as surrounding farms that are artificially watered. Farming by rainfall alone here is not unlike farming in Kentucky, Tennessee, southern Missouri, and northern Arkansas. The rainfall in Italy is, if anything, a little greater and is equally well distributed.

In the fields devoted to wheat only one crop a year is grown where irrigation is not practiced, but where the land is irrigated a good crop of corn, beans, or cabbage can be planted and brought to maturity after the wheat is harvested. Without irrigation, clover and alfalfa, if sown with wheat, make a small growth, but with irrigation a good crop can be cut the same year after the wheat is harvested, and the stand in succeeding years is better because of the vigorous growth while the plants were young, due to irrigation.

It is not alone in theory that the valleys of western Oregon need irrigation; it is a fact. It is only necessary to observe the appearance of the valley lands in the latter part of July, in August, and in September. They are parched and brown at the very time they should be producing their maximum crops. Where clover is being raised the second crop stands a few inches high, scorched and dry. Other crops not located on bottom land are in the same condition. The vigorous growth that should be seen is lacking. All production is at a standstill during this the best season of the year, waiting for the "fall rains" to begin. As the direct effect of this condition the dairy herd is put upon winter rations in the summer time. Cows can be provided with green food the winter through and during the spring and fall seasons, but in the summer time they are put on dry hay and mill feed. Hay sells for $14 to $18 per ton and mill feed for $25 to $28 per ton, which at once creates abnormal conditions. Each year hundreds of thousands of dollars' worth of ham, bacon, lard, butter, eggs, and canned goods are shipped into these valleys from outside the State for consumption here; and all this in an agricultural section that should be exporting all such products instead of importing them. Verily there is need for irrigation in these valleys of western Oregon.

EXPERIMENTAL INVESTIGATIONS.

To determine just what benefit would result from irrigation, a series of experiments under field conditions were undertaken. This work was confined entirely to the Willamette Valley. It was begun in the spring of 1907 and has been continued through the seasons of 1908 and 1909. On account of the varying soil conditions, it seemed desirable to have the experimental tracts so located as to include the representative soil types. The main part of the experimental work and observations has been confined to the sections near Corvallis, Albany, and Hillsboro, where opportunity was afforded for a study of nearly every phase of the general problem.

All experimental work has been carried on under cooperative arrangements with those whose substantial interest has made it possible to do much more with the funds available than would have been the case if the Office of Experiment Stations had been forced to bear the entire expense of equipping and conducting the experimental tracts. The cooperators with the Office in this investigation and the location of the experimental tracts, are as follows:

(1) The Oregon Agricultural Experiment Station. The tract used was part of the station farm located 1 mile west of Corvallis, in Benton County.

(2) George R. Bagley. This farm lies 6 miles northwest from Hillsboro in Washington County.

(3) Cockerline and Howard. This farm lies 2 miles south of Albany in Linn County.

In addition to the experimental work at these three places, observations as to the effect of irrigation have been made at different times during the period of investigation on the following places where irrigation has been adopted recently.

Oswald West's hop yard, 3 miles south of Corvallis, Benton County.

Johnson and Bryson's ranch, 3 miles north of Monroe, Benton County.

Robert Gallatly's ranch, 3 miles south of Philomath, Benton County.

H. Hunteman's farm, 2 miles west of Hillsboro, Washington County.

Z. Wood's farm, 1 mile west of Hillsboro, Washington County.

F. B. Chase's market garden, 1 mile north of Springfield, Lane County.

IRRIGATION AND CULTURAL METHODS EMPLOYED.

Although the experimental tracts were located in different sections of the Willamette Valley, and each presented entirely different conditions, the crops raised, the cultural treatment, and the irrigation methods employed were kept as nearly uniform as possible throughout all the experiments, so that a comparison of results would be possible, and also for the purpose of more easily locating any errors or mistakes that might have occurred. As the methods employed were exactly the same on all the experimental tracts, they will be discussed under the following general head:

PREPARATION OF LAND FOR IRRIGATION.

Subsoiling.—On all the stations, with the exception of the state experiment station, the land used had at one time or another been cropped extensively to wheat, with the result that a hard, impervious plow sole or artificial hardpan had been formed at about 6 inches beneath the surface. It has been noticed generally by farmers, especially those who have come to the Willamette Valley from other sections, that the average soils here are more or less unresponsive to cultivation and that they require much more work to make them produce than soils of many other localities. This condition is due in a large measure to the existence of this plow sole and to the condition of the surface soil for which it is responsible. This plow sole isolates the few inches of surface soil from the deeper and unexhausted subsoil and not only cramps the root development of plant but serves as an effective barrier to the passage of moisture in either direction. To break up this plow sole the land put into irrigated

crops was thoroughly subsoiled. This was accomplished by plowing 8 to 10 inches deep with an ordinary walking plow and following in the furrow with the subsoiler put down another 8 inches. This stirred the soil thoroughly to a depth of 16 to 18 inches and completely destroyed the artificial hardpan. Very little of the subsoil was brought to the surface by this operation and nothing but beneficial effects have been noticed on the tracts so treated. The subsoiling was done with three and four horses, at a cost about the same as for an ordinary deep plowing.

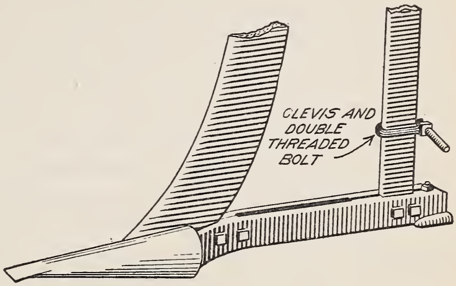

FIG. 4.—Subsoiler used on Bagley farm.

Two types of subsoil plows were used. The type shown in figure 4 seemed to give the best results on the lighter soils of the Hillsboro farm, while the type shown in figure 5 seemed to give the best results on the Albany farm, where the soil is of a heavier nature. The bolt and clevis attachment on the rear standard, shown in figure 5, was found necessary to more thoroughly break up the subsoil loosened and raised by the shoe. This was put on after the work had begun and was found to leave the subsoil in the furrow in much better condition than where it was not used.

Plowing.—The plowing was done with an ordinary 14-inch walking plow and three horses, to a depth varying from 6 to 10 inches. After plowing and subsoiling, the land was struck in both directions with an ordinary drag harrow, which left it ready for leveling.

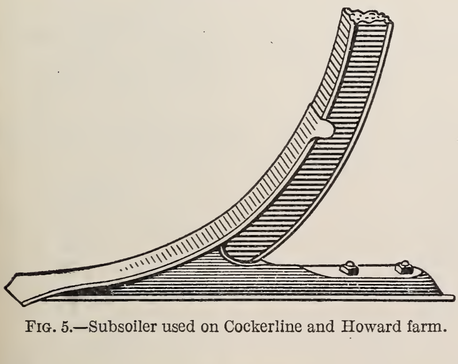

FIG. 5.—Subsoiler used on Cockerline and Howard farm.

Leveling.—Before any land is ready for irrigation, and especially the lands in the Willamette Valley, where to prevent baking of the surface a minimum amount of water should be applied, it should be trued up and brought to a uniform slope free from depressions and potholes in which water could collect and stand. In leveling the fields being experimented upon and in preparing them for irrigation, the leveler shown in figure 6 has proved very successful. This leveler has been used quite extensively in eastern Oregon and eastern Wash-

ington on the light ash soils of those sections, and from the experience gained in the Willamette Valley it seems to be well adapted to the heavier soils found there and, where properly handled, will give results that are very satisfactory.

Two sizes of leveler were used, one 12 feet long and requiring four horses; the other 16 feet long and requiring six horses.

Either size can be operated by one man, both rough work and the finishing being done with the same implement. Where the land is very uneven, the whole field is not plowed, to begin with. The tops alone of all high places are plowed and the earth moved into the low places until the whole surface is brought to a fairly uniform slope. With this rough work done, the field is then plowed and the surface finished by light leveling. All ditch lines should be located before the land is leveled, so that in the process of leveling the proper slope may be given the land with regard to the laterals that are to supply the water.

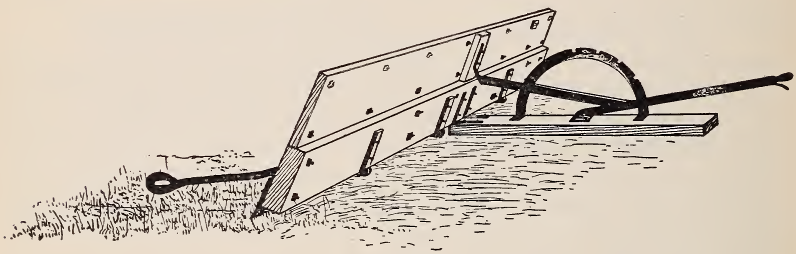

FIG. 6.—Leveler used in preparing land on experimental tracts.

The cost of preparing land for irrigation will of course vary with different conditions, but to convey some idea of what the cost should be on average lands in the Willamette Valley, the following cost data are given.

In preparing 5 acres of rather smooth land for alfalfa on the West farm the past season, the following expense was incurred:

Plowing, 3 days, at $4 per day	$12.00
Leveling, 2 days, at $4 per day	8.00
Harrowing, 2 days, at $3 per day	6.00
Furrowing land, 1 day, at $3 per day	3.00
Total cost ready for seeding	29.00
Cost per acre	5.80

The cost of leveling alone on 20 acres on the Bagley farm amounted to $25, giving an acreage cost of $1.25 per acre. These costs, it should be noted, are low, owing to the naturally level character of the land. They represent quite truly, however, the prairie class of land, of which there are thousands of acres in the valley.

IRRIGATION METHODS.

Securing a water supply.—In securing a water supply for irrigation two methods have been employed. On the Albany farm the supply is obtained by gravity flow from a large power canal which flows through the tract that is being used for experimental purposes. On all the other farms the water is secured by pumping from bodies of open water. On two of these places gasoline engines have been installed to supply the power to drive the centrifugal pumps, while on the other farm—that of Mr. Bagley near Hillsboro—the power for driving the centrifugal pump is derived from a turbine water wheel, which in the past has been used to supply power for an old grist mill that is on the property. By employing these different methods of securing water it has been possible to demonstrate the chief ways in which water for irrigation may be secured and to determine their relative effectiveness.

Distribution and application of water to fields.—With the fields leveled and the water supply provided, the next question naturally arising is how best to apply the water to the soil so as to produce the most beneficial results. Sandy soils have little tendency to bake under irrigation, but the direct application of water to the surface of clayey soils is attended by the formation of a hard crust on the surface, which, if it can not be broken by cultivation, seriously retards the growth of the plant. This crust forming and baking process is also attended in practically all of the clay loams of the Willamette Valley prairie lands by a "running together" of the soil particles where too great a degree of saturation is permitted. To avert these difficulties the furrow method of irrigation has been adopted almost exclusively. By this method water can be applied in irrigation without wetting the surface soil except immediately adjacent to the furrow, and thus all damage from baking or running together is obviated. In laying out a furrow system the field must be brought to a comparatively uniform slope, and after the crop is seeded small furrows 2 to 4 inches in depth are run in a direction that will give the proper slope, at intervals of 30 to 36 inches. The water is admitted to these small furrows from a head ditch or flume, and a small stream is permitted to flow into each until the soil between the furrows has become thoroughly subirrigated, producing the condition shown in figure 7. In making these furrows the implement shown in figure 8 has been used on the experiment farms. It makes three furrows at

FIG. 7.—Sketch showing subirrigated condition where furrows are used.

once, 30 inches apart. The short rounded timbers which make the furrows are shod on their front end with a piece of sheet steel to prevent wear on the corners. The arm extending to the left carries a

FIG. 8.—Furrower, or marker.

marker, which traces a line in the soft earth, showing where the outside shoe must follow on the return trip across the field. This furrower is operated with two horses and is weighted by the driver standing on the platform. The cost was $13 for the marker complete as shown in the figure.

FIG. 9.—Head flume used in distributing water.

Methods of distribution.—Both the open head ditch and small wooden flume have been used in the distribution of water to furrows. Figure 9 shows the water being distributed from a head flume. This

flume is made of 1-inch lumber and is 12 inches wide and 12 inches deep. Water is discharged into the furrows through 1-inch holes bored in the side of the flume, the flow from each orifice being controlled by a lath button fastened to the side of the flume with one nail in such a manner that it will cover all or part of the orifice, as desired. The length of the furrows shown in the figure is 275 feet, which has been found to be about the right length for furrows on the prairie soils of the valley.

The method of distributing water from a head ditch is illustrated

FIG. 10.—Method of distributing water from head ditch by means of lath spouts.

in figure 10, which is a photograph taken on the Bagley farm, showing the irrigation of corn. The head ditch was made by turning a deep furrow either way and with a shovel cleaning out the rough channel thus formed. The grade of the ditch was about 1 foot per hundred. The water was checked in the ditch by means of a canvas dam made from an old binder apron, the canvas being nailed to a crosspiece of 1 inch by 4 inch timber, as shown in figure 11. The crosspiece was long enough to reach from bank to bank and the

canvas sheet 4 feet square was large enough to reach from one side of the ditch to the other and cover quite an area on the bottom of the ditch. By putting a few shovelfuls of earth on the edges of the canvas an effective dam was secured. The water, after being checked by the canvas dam, was admitted to the furrows through spouts placed in the ditch bank. Four of these spouts are shown on the ditch bank in figure 10. They were made of ordinary lath, as shown in figure 12, a 4-foot length making two spouts. With the head used, 300 gallons per minute, it was possible to supply from 15 to 18 streams at one setting. After the water had remained in the furrows from four to six hours, the dam was moved down the head ditch and a new set of furrows supplied. In the use of this method of distribution a very even irrigation could be applied, with no danger of flooding the surface soil if the land had been sufficiently leveled. The water gradually seeped from the furrows into the soil, saturating the subsoil and leaving the surface soil comparatively dry. In the course of a day or two the excess of water in the subsoil would gradually be drawn to the surface by capillarity and thus moisten the soil surrounding the root system of the plant.

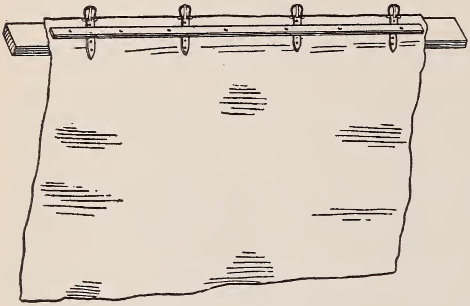

FIG. 11.—Canvas dam made of old binder apron.

Cultivation after irrigation.—To conserve the moisture that had been placed in the soil and to break up the crust that might form in the bottoms of the irrigated furrows, all crops in rows were cultivated with a 1-horse cultivator as soon after irrigation as possible. This not only loosened the surface soil in the furrows, but left it in fit condition for subsequent irrigation.

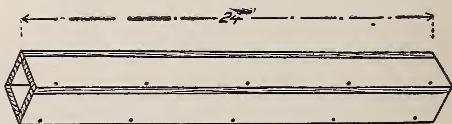

FIG. 12.—Method of making lath spouts.

CLIMATIC CONDITIONS DURING PERIOD OF INVESTIGATION.

Climatic conditions during 1907 and 1909 were practically normal. During 1908, conditions were abnormal in that a late cold spring was followed by an early killing frost in the fall, and as a result the usual season of crop growth was greatly shortened. Aside from the shortness of the season, average conditions in general prevailed in 1908.

CLIMATIC CONDITIONS IN 1907.

Weather conditions during the twelve months of 1907 may be briefly summarized as follows:

January.—Unusually cold; precipitation slightly above normal.

February.—Normal conditions prevailed.

March.—Slight deficiency in rainfall; otherwise normal conditions prevailed.

April.—Normal conditions prevailed.

May.—Warm and dry; precipitation below normal.

June.—Temperature normal. Rainfall slightly above normal; beneficial showers, 10 to 14, and 21 to 22.

July.—Temperature normal. Rainfall slightly below normal and occurring in scattered showers.

August.—Normal conditions prevailed.

September.—Normal conditions prevailed except for slightly higher temperatures.

October.—Mild temperatures and very dry.

November.—Normal conditions prevailed.

December.—Precipitation abnormally heavy.

The crop-growing season of 1907 represented normal conditions almost throughout the period. The dry period came on about three weeks earlier than usual, beginning early in May, but well-distributed showers in the middle and latter part of June relieved the droughty condition then existing. During July, August, and September scattering showers were received at intervals, but these were of local nature and in most cases were so slight as to do little good. Irrigation was commenced on the different tracts during the first ten days in July, and from that date to September 15 typical droughty conditions existed.

CLIMATIC CONDITIONS IN 1908.

Weather conditions during 1908 were, in brief, as follows:

Climatic conditions in Willamette Valley, 1908.

January.—Unusually dry and mild, remarkably even temperature, rainfall deficient.

February.—Mild and dry, precipitation in form of rain entirely.

March.—Normal temperatures, marked deficiency in precipitation.

April.—Sharp contrasts in temperature, heavy frosts end of month, two storm periods 3 to 6, and 15 to 24.

May.—Excessive cloudiness accompanied by low temperatures, rains frequent and heavy, conditions not conducive to good crop growth.

June.—Average conditions prevailed, precipitation somewhat below normal, principal shower period 15 to 23.

July.—Warm and very dry, precipitation only one-fourth normal, distributed in three light shower periods, 3, 12, and 13.

August.—Temperatures normal, rainfall above normal, no rain before the 12th, occurred in two periods 12 to 13, and 17 to 25.

September.—Low temperatures, exceptionally low rainfall, killing frosts 23 to 26.

October.—Normal conditions, heavy rainfall 10 to 20.

November.—Marked deficiency of precipitation.

December.—Unusually dry and cold.

The entire crop-growing season of 1908 was rather exceptional in character and was not conducive to the best growth of crops. Following an exceptionally open and mild winter, the spring season was of unusual severity, being rainy and cold until late in the season; spring cultivation and seeding was delayed nearly a month in some sections. Following the cold spring a hot, dry summer came on abruptly, with the result that on the experimental tracts it was necessary to "irrigate up" some of the crops. Owing to the heavy nature of the valley soils this procedure was not attended with success, and as such a practice would ordinarily be unnecessary, abnormal conditions were at once created. All the crops being experimented upon were, under the conditions described, three or four weeks behind in their growth. To complete the abnormality of the season, a killing frost occurred on September 23 and 24, and did great damage throughout the valley and on the experimental tracts, killing most of the crops from which it was hoped definite results would be secured. With but few crops matured when this freeze occurred, it will not be possible to give accurate results of yields under irrigation in 1908, except for those crops that were not seriously damaged. A full and complete description of the appearance of the crops will be given, however, so that in the absence of definite results some idea may be had of the effect of the irrigation during the dry summer season.

The amount of summer rainfall in 1908 was about normal. The dry period extended from June 12 to September 12 and later. During those three months the total rainfall was 2.5 inches. This, it is seen, is practically the normal. The distribution of this rainfall was very uneven. The greater part of June was dry, a small shower period occurring from the 15th to the 23d. July was excessively dry, only 0.04 inch of rainfall occurring during the entire month, and this came in light scattered showers, which did no good whatever. In August no rain fell until the 12th, when the six-week drought was broken by a two day shower period during which 1 inch of rain fell all over the valley. Toward the end of August there was another shower period, but the rain was so light and the soil so dry that little permanent good was done. From August 28 to October 10 droughty conditions prevailed throughout the valley. On October 10 heavy rains set in, closing the dry season for the year. Had other weather conditions been as nearly normal as the rainfall, the season of 1908 would have been an excellent one for experimental work. The late cold spring and the killing frosts in the early fall made the season so short however, that it was impossible to secure the proper growth of crops.

CLIMATIC CONDITIONS IN 1909.

Weather conditions during 1909 were as follows:

January.—Remarkably cold weather with heavy snows during first of month. Latter half of month mild with frequent rains; precipitation greater during month than for any other January for 20 years.

February.—Almost continuous rainfall; with two exceptions precipitation was the heaviest of any February for 20 years.

March.—Rainfall about one-half normal; temperatures slightly above normal.

April.—Extremely dry with low temperatures and frequent killing frosts.

May.—Unusually dry and cool; heavy shower period closed the month and improved crop conditions greatly.

June.—Warm and dry with showers in middle and toward end of month.

July.—Normal conditions prevailed.

August.—Normal conditions prevailed.

September.—Temperatures normal; rainfall somewhat below normal.

October.—Normal conditions prevailed.

November.—Excessive rainfall causing heavy floods in all streams.

December.—Unusually cold, with heavy snow fall general over the Northwest.

Aside from a very dry and rather cool spring during April and May the crop growing season of 1909 may be considered quite normal. The drought and cool weather of these two months did not seriously affect crop growth, for with a good general rain the last of May along with high temperatures early in June, all crops received a good start in their growth. Two rather general showers, one the middle of June and one about July 4, brought crops to their normal condition. The dry period set in immediately after the rains in the first week of July and irrigation was commenced shortly after that time. Favorable conditions continued until harvest on all the experimental tracts. The continued drought during July, August, and September told heavily on all crops not favorably located. With conditions so nearly normal therefore, both as to rainfall and temperature, the season of 1909 may be considered as very favorable for the experimental work.

The rainfall during the period of investigation, as shown by the United States Weather Bureau records at Portland, Corvallis, Albany, and Eugene, is given in the following table:

Precipitation at different points in Willamette Valley during period of investigation, 1907, 1908, and 1909.

Month.	Portland.			Corvallis.			Albany.			Eugene.			Average.		
	1907.	1908.	1909.	1907.	1908.	1909.	1907.	1908.	1909.	1907.	1908.	1909.	1907.	1908.	1909.
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
January	8.23	4.73	9.29	8.97	4.24	13.61	7.54	3.92	8.77	7.91	2.82	7.95	8.15	3.93	9.85
February	3.54	2.85	7.03	5.38	4.10	9.45	4.81	3.02	7.61	6.07	2.67	7.71	4.95	3.16	7.95
March	3.86	4.39	2.35	5.39	4.33	1.93	4.43	3.86	1.81	4.65	2.87	1.76	4.58	3.86	1.96
April	3.57	3.38	.89	2.98	1.99	.26	2.70	1.64	.56	4.03	.81	.43	3.32	1.96	.54
May	1.37	4.66	1.79	1.27	2.89	1.39	1.28	2.76	1.32	1.38	2.46	3.37	1.33	3.19	1.97
June	1.84	.67	.17	1.11	1.38	.30	1.30	.86	.22	1.40	1.76	.43	1.41	1.17	.28
July	1.19	.05	2.26	.24	0	1.10	.44	.08	1.34	.18	.02	.75	.51	.04	1.36
August	1.02	1.34	.05	1.15	1.00	.11	1.10	.82	.30	1.47	.76	0	1.19	.98	.12
September	1.73	.23	.95	1.17	.23	1.16	1.15	.40	.93	1.23	.37	1.11	1.32	.30	1.04
October	.93	5.17	2.01	1.32	4.34	4.51	1.21	3.68	4.02	1.33	5.04	3.54	1.20	4.56	3.52
November	6.51	3.10	12.49	7.92	4.01	11.53	6.78	4.07	11.86	4.69	3.67	8.51	6.48	3.71	11.10
December	9.10	3.80	4.47	13.33	4.78	.....	11.70	3.43	4.96	11.93	3.96	3.60	11.52	3.99	3.26
Total	42.89	34.37	43.75	50.23	33.29	.....	44.44	28.54	43.70	46.27	27.21	39.16	45.96	30.85	42.95

EXPERIMENTS IN COOPERATION WITH THE AGRICULTURAL EXPERIMENT STATION, CORVALLIS, OREG.

Under the terms of the cooperative agreement between the Office of Experiment Stations and the State Agricultural Experiment Station, the station provided a tract of 10 acres for experimental purposes and planted, cultivated, and harvested all crops, while the Office provided and installed the pumping plant, laid out the irrigation system, and attended to the irrigation work.

Water was secured from Oak Creek by means of a pumping plant, which was installed in 1907. The pumping equipment consisted of a 4-horsepower gas engine and a $3\frac{1}{2}$-inch centrifugal pump. During the seasons of 1907 and 1908 the water was lifted to a height of 15 feet

FIG. 13.—Corvallis irrigation plats.

and discharged into a flume 700 feet long that delivered it to the experimental plats, located during these two seasons on the north side of the Corvallis and Eastern Railroad track. In 1909 the experiment was moved to the south side of the track, where better soil conditions prevailed and where the pumping plant could be located on experiment station land. The pumping plant in its new location still takes its supply from Oak Creek, but the lift is increased to 19 feet. The arrangement of plats in the new location with regard to the distributing flume is shown in figure 13. The photograph is taken from the roof of the pump house. All crops were planted in duplicate plats, the irrigated plats lying to the left of the flume and the unirrigated to the right.

The discharge of water is measured over a 1-foot trapezoidal weir placed at the end of the main distributing flume. When the engine

and pump were up to full speed the discharge in the flume was measured over the weir, the water escaping down a waste ditch. When the flow had become constant it was turned out upon the plat to be irrigated. After the irrigation of each plat another observation of the flow over the weir was taken. In this way it was possible to use the weir as a measuring device without loss of head in the distributing flume.

The soil being experimented upon is a rather heavy gray clay loam typical of many thousands of acres in this section of the valley. The subsoil is heavier clay. The surface drainage is good, the land having a general slope toward Oak Creek on the west and south, while a small part slopes toward the north into a slight depression that also drains toward the creek. The land used in 1907 and 1908 had been in cultivation for a number of years, while the land used in 1909 had been in cultivation to oats but one year. Prior to that time it had been used for several years as pasture.

RESULTS IN 1907.

In 1907 the following crops were irrigated, with the results shown:

Corn.—A plat of one-half acre was planted to field corn on June 14. On June 29, when the corn was about 3 inches high, the land was irrigated for the first time. In a few days the irrigated corn showed the effect of the watering very plainly, and in three weeks it had a decided advantage in growth and vigor over the plat of unirrigated corn. On July 29 the second irrigation was given to a part of the plat which received the first irrigation. During the first week in October the crop was harvested and the following yields were secured:

Yield of irrigated and unirrigated corn at Corvallis, Oreg., 1907.

Treatment.	Green fodder per acre.	Increase.
	Pounds.	*Per cent.*
Unirrigated	5,647	....
Irrigated once	7,000	24
Irrigated twice	9,666	71

Potatoes.—The area planted to potatoes was the duplicate of that planted to corn. The potatoes were planted at the same time as the corn and received the same cultural treatment. The yields were as follows:

Yield of irrigated and unirrigated potatoes at Corvallis, Oreg., 1907.

Treatment.	Yield of marketable tubers per acre.	Increase.	Marketable tubers.
	Pounds.	*Per cent.*	*Per cent.*
Unirrigated	2,604	....	89.2
Irrigated once	6,760	160	88.0
Irrigated twice	7,500	180	93.2

RESULTS IN 1908.

In 1908 an effort was made to include, in addition to the above crops, alfalfa, vetch, and clover. Plats of clover and vetch were planted in the fall of 1907 and a plat of alfalfa was planted in the spring of 1908. Unfortunately, however, none of these crops produced a stand. From a plat of second-year clover, however, results were secured which illustrate the value of irrigation on clover which has once become established.

The results secured from the various crops raised in 1908 are as follows:

Corn.—A plat of 1.44 acres was planted to field corn on June 15, 1908. It was irrigated once on August 1 and 2. Water should have been applied several days earlier, but owing to a breaking of one of the parts of the engine the application of the water was delayed. The weather at the time was very warm, and the corn not irrigated showed the effects of the drought by curling of leaves and a general wilted condition. The effects of the water was noticeable at once in the increased vigor of the plants and their ability to stand the hot sun with no indication of wilting or curling. No yield of mature corn was secured, as the frost of September 23 prevented ripening and the crop had to be cut for fodder. The yields of green fodder cut from the plats are reported in the following table in terms of pounds per acre:

Yield of irrigated and unirrigated corn at Corvallis, Oreg., 1908.

Treatment.	Green fodder per acre.	Increase.
	Pounds.	*Per cent.*
Unirrigated	7,280	
Irrigated once	9,640	32.4

Potatoes.—One-twelfth of an acre of potatoes was planted on June 15. They were irrigated and cultivated in the same manner as the corn just described. The frost also caught these before the tubers were fully matured, so that no fair statement of comparative yields can be given. The yields were as follows:

Yield of irrigated and unirrigated potatoes at Corvallis, Oreg., 1908.

Treatment.	Yield of market-able tubers per acre.	Increase.	Marketable tubers.
	Pounds.	*Per cent.*	*Per cent.*
Unirrigated	3,626		66.6
Irrigated once	5,041	39	88.4

Beets.—Red beets, given the same cultural and irrigation treatment as the potatoes and corn, yielded the following partial results on a plat containing one-twelfth of an acre:

Yield of irrigated and unirrigated beets at Corvallis, Oreg., 1908.

Treatment.	Yield per acre.	Increase.
	Pounds.	*Per cent.*
Unirrigated	2,725	
Irrigated once	4,309	58.1

Clover.—Duplicate plats of second-year clover containing 1.12 acres each were made the subjects of experiment under irrigation, both being given the same treatment except as to irrigation. The clover was planted in March, 1907, with wheat. The clover gave no yield in 1907, but was in bearing in 1908. The first crop of clover was not irrigated, water being applied to the second crop only. The watering of the irrigated plat was begun on July 23, but was not completed at that time owing to a breakdown of the pumping plant, which delayed the completion of the irrigation till August 9. Had it been possible to complete the irrigation at the time the water was first applied, a much heavier crop would have been cut from the irrigated plat. The yields from the plats were as follows:

Yield of irrigated and unirrigated clover at Corvallis, Oreg., 1908.

Crop.	Unirrigated plat, yield per acre.	Irrigated plat, yield per acre.	Increase.
	Tons.	*Tons.*	*Per cent.*
First crop	4.44	4.44	
Second crop	.63	2.02	220.6
Total	5.07	6.46	27.4

It is unfortunate that more comprehensive and detailed results can not be presented from the Corvallis station for the season of 1908, but the adverse conditions encountered absolutely prevented. Even under these circumstances, however, some results were secured which show unmistakably that irrigation can be made of immense benefit to crops that extend their growth through the summer.

RESULTS IN 1909.

The crops raised in 1909 were potatoes, sweet corn, field corn, Kafir corn, alfalfa, clover, beets, and kale—no reports are available, however, on the Kafir corn, beets, and kale. The land before being seeded was plowed and harrowed, then leveled for irrigation, after which it was disked and then given a final harrowing. The cultivated crops were given five cultivations during the season on the following

dates: June 12, June 21, July 8, July 15, August 5. Crops showed no need of moisture until about July 20. All the crops were given a heavy irrigation between July 22 and July 26, which application under the circumstances was sufficient to carry them to maturity.

The results secured from the various crops, are as follows:

Corn.—A plat of 0.25 acre was planted to Hendricks Early field corn on May 5. It was irrigated once on July 22, water to a depth of 0.65 foot being applied. Part of the plat was planted thin while another was planted thick to determine the effect of thin and thick planting. The following table compares the yields from this plat with a similar plat that received no irrigation:

Yield of irrigated and unirrigated corn at Corvallis, Oreg., 1909.

Treatment.	Green fodder per acre.	Increase.
	Pounds	*Per cent.*
Thick planted:		
Unirrigated	11,125	
Irrigated	14,153	26
Thin planted:		
Unirrigated	11,000	
Irrigated	11,895	8

Potatoes.—A plat containing 0.592 acre was planted to Burbank potatoes on May 3. It was irrigated July 23, water to a depth of 0.54 foot being applied. When the crop was harvested, on October 24, the potatoes were of good size but showed scab and second growth. The yield was as follows:

Yield of irrigated and unirrigated potatoes at Corvallis, Oreg., 1909.

Treatment.	Yield per acre.	Increase.
	Bushels.	*Per cent.*
Unirrigated	150	
Irrigated	215	43

Sweet corn.—A plat containing 0.124 acre of Early Minnesota sweet corn was planted May 5. It was irrigated once on July 22, water to a depth of 0.65 foot being applied. It received the same cultivation as the field corn and potatoes. The yield, compared with a similar plat not irrigated, is shown in the following table:

Yield of irrigated and unirrigated sweet corn at Corvallis, Oreg., 1909.

Treatment.	Yield of fodder per acre.	Increase.
	Pounds.	*Per cent.*
Unirrigated	7,000	
Irrigated	13,750	96

A plat containing 0.124 acre was also planted to Stowell Evergreen sweet corn. This received the same cultural treatment and the same amount of water as the Early Minnesota. The yield of this variety on the unirrigated plat compared with that on the irrigated plat is as follows:

Yield of irrigated and unirrigated sweet corn at Corvallis, Oreg., 1909.

Treatment.	Yield of fodder per acre	Decrease.
	Pounds.	*Per cent.*
Unirrigated	10,936	
Irrigated	10,726	2

Clover.—A plat containing 0.95 acre was planted to a mixture of red clover and alsike clover, on May 14, 7 pounds of red clover and 3 pounds of alsike being used per acre. Water was applied July 24 and 25 to a depth of 0.69 foot. The growth after this irrigation was very rapid and most marked in contrast with the plat not irrigated. The clover on the unirrigated plat after it reached a height of about 4 inches made no further growth during the entire season. On the other hand the irrigated plat grew vigorously and on August 16 was high enough to cut with the mower, on which date 1,333 pounds of green clover was taken off. It revived quickly after this cutting and went into the fall in far better condition than the unirrigated plat. The first year of course is not a fair test with clover for it does not come into full bearing until its second year. With the good start that it has, however, it may be expected that this plat will make a splendid showing the coming season.

Alfalfa.—A plat containing 1 acre was planted to alfalfa and given the same amount of water as the clover. No crop was harvested, however, as it was simply clipped at intervals during the season in order to secure a good stand for coming seasons. A splendid growth was secured and this plat promises well for the future.

EXPERIMENTS IN COOPERATION WITH G. R. BAGLEY, NEAR HILLSBORO.

The tract upon which these experiments were conducted is located about 6 miles north of Hillsboro. Prior to the purchase of the tract by Mr. Bagley in 1906, the land had for many years been used exclusively for grain growing. It is now being developed as a diversified farm, and irrigation, which is easily and cheaply provided, is being employed in its development. A dairy herd is being kept on the property, so that a practical test of the value of irrigation has been possible.

The soil is representative of the prairie soils common to the north end of the valley and may be classed with the gray clay loams. On wetting it becomes a very dark gray in color and is quite sticky. It takes water readily and subirrigates for long distances, making it an easy soil to irrigate. On the farm of Mr. N. H. Campbell, which adjoins the Bagley farm and where irrigation has been tried also, water has subirrigated laterally from a head ditch across a plowed field, a measured distance of over 120 feet. Such a condition as this is very exceptional, even in the most favored irrigated sections of the West.

Water for irrigation on the Bagley farm is secured from Dairy Creek through an old mill race which is part of the property owned by Mr. Bagley. In applying the water to the parts of the farm that were irrigated, both gravity flow and pumping were resorted to. The 8-acre tract upon which experiments with red clover were made is irrigated by gravity flow through a small ditch taken out of the forebay just above the mill. Owing to the mill race being located on the lowest level of the farm, it is not possible to supply much of an area with this water by direct gravity flow. To increase the irrigated area an 8-inch horizontal centrifugal pump was installed in the mill, the water being taken into the pump directly from the penstock. The power for driving the pump was taken from the main line shaft of the mill, which is belt connected to a turbine wheel which operates under 14-foot head and is capable of developing 45 horsepower. The discharge pipe from the pump is taken to a valve chamber outside the mill, from which two lines of pipe can supply the entire farm. One of these lines of pipe, the length of which is 1,760 feet, was laid in 1908. It is a 6-inch, machine-banded, first-grade pipe. The other line has not yet been laid, but the connections for it were all installed at the time the 6-inch line was put in. It will be about the same length, but will have a diameter of 10 inches in order to serve the larger area under it. The 6-inch line serves an area of 30 acres, while the 10-inch line will serve an area of about 70 acres.

The capacity of the line, with the pump running up to a speed of 600 revolutions, is 400 gallons per minute. The capacity of the 10-inch line when installed will be about twice this amount.

RESULTS IN 1908.

It was planned to experiment with corn, kale, beets, turnips, and cucumbers on the tract supplied with pumped water, but owing to damage done by the killing frost in September, no definite results can be reported for these crops. It will be possible, however, to give some partial results showing the benefit derived from irrigation. In addition to these crops, experiments were also made with alfalfa and with clover under irrigation. The frost did no serious damage to these and complete results can be reported.

Corn.—Five acres of field corn were planted June 15 to 20. It should have been planted at least two weeks earlier, but the late spring rains prevented an earlier preparation of the land. With this late seeding, however, a good rapid growth was secured, and even though it was behind most of the corn on neighboring farms in its early stages, it soon caught up in its growth during the latter part of July when the weather became very hot. Water was first applied July 16, when the corn stood about 2 feet high. The effect of this first irrigation was most noticeable during the hot spell that immediately followed. Corn in other sections of the valley was plainly suffering from the heat and from lack of moisture, as indicated by the curling leaves. The irrigated corn showed not only increased vigor during the hot weather, but soon gained the ground it had lost due to late planting. A second irrigation was begun August 9, and enough water was applied to bring the total up to approximately 8 inches in depth. After this no more water was applied. The corn grew rapidly, and by September 1 had attained an average height of between 6 and 7 feet. A good yield seemed assured, the ears developing uniformly and being of good size and quality, but just as it was passing out of the milk stage the heavy frosts of September 23 to 25 stopped all further growth. Although yet immature, even for silage, it was cut and placed in the silo. The yield of the crop as harvested under these conditions was 8,000 pounds per acre. This, however, is much below the actual weight of green fodder produced, because the effects of the frost and subsequent wilting reduced the weight very materially.

Kale.—Three acres of "Thousand headed" kale were planted from the seed at the same time the corn just mentioned was planted. It was also given the same cultural treatment. This crop was of course not hurt by the frost. The yield was 30 tons per acre. This is not a large yield, but the beneficial effect of irrigation on the kale plants themselves in their younger stages was most marked.

Beets.—One acre of mangel wurzels was planted at the same time as the corn and kale. A very poor stand was secured, however, and the growth, like that of the corn, was checked by the frost. The yield of beets from the 1 acre was 12 tons. This yield, however, does not thoroughly indicate the effect of the water used in irrigation, for the benefit they derived was most marked. Much of the seed, owing to the dry spring weather, did not germinate until after the first irrigation, and these beets, it will be realized, could not make much of a growth. The seed that did germinate in proper season produced large, well-formed beets which with the assistance of the water attained their full size despite late planting.

Cucumbers.—One-fourth of an acre was planted to pickling cucumbers. These showed a splendid growth throughout the entire season.

The beneficial effect of irrigation was most noticeable in that a thrifty growth was maintained during the entire dry season. The vines were just in their prime when the frost killed them. The yield from the one-fourth acre plat was 2 tons.

Beans.—One acre was planted to little white navy beans that also showed a splendid growth under irrigation, but these, too, were killed by the frost just as the pods were beginning to ripen.

Alfalfa.—Realizing from the results of the experiments of 1907 that one of the greatest benefits to be derived from irrigation was in the production of leguminous forage crops, an experiment in the production of alfalfa under irrigation was begun. Alfalfa is not an easy crop to raise in the Willamette Valley on account of the difficulty of getting it started successfully. It is being raised, however, in certain sections of the valley with marked success. At the State Experiment Station at Corvallis, for instance, there is an alfalfa field 7 years old which produces splendidly, yielding 5 tons of hay per acre on the average. The greatest difficulty is experienced in most cases, however, in securing a stand, and the numerous failures have developed the erroneous idea that alfalfa can not be raised in the Willamette Valley. A variety of reasons may be assigned for these failures, among which the most important seem to be: (1) Improper and insufficient artificial inoculation of the soil with nitrifying bacteria, the Willamette soils generally being sterile in this regard; (2) poor preparation of the seed bed; (3) poor selection of soil, which should be light in texture and well drained; (4) planting of varieties of seed not adapted to soil and climatic conditions of the Willamette Valley; and (5) drying out of the soil during the dry summer season, which not only stunts the growth of the young plant, but actually kills it before it can gain a sufficient root hold.

The seed which has been tried in the valley has come largely from Utah. Some of this has been successful, but it does not seem to be adapted to local conditions, and most of it has failed. With a view to trying a variety more adapted to Willamette conditions, a small amount of seed of what is known as Arabian alfalfa was secured from the Bureau of Plant Industry. This variety, as its name implies, had its origin in Arabia. It is claimed that its growth is more vigorous than that of the ordinary variety, that it recovers quickly after cutting and that its growing season is much longer than that of the ordinary variety, commencing earlier in the spring and continuing later in the fall. It has shown in actual tests its ability to produce three cuttings in sixty days, where under the same conditions the ordinary variety produced but two.

Enough seed was secured to plant one-half acre. A duplicate plat was planted with Utah seed for sake of comparison. The land was subsoiled and thoroughly worked before seeding and was inoculated

with old alfalfa soil secured from the State Experiment Station farm at Corvallis, about 400 pounds of alfalfa soil being applied to the two one-half acre plats. The seed of both varieties was planted on May 30. The Arabian seed came up quite evenly, while the Utah seed was more or less spotted. On July 15 the Arabian plants showed an average height of 8 inches, with some plants around the edge of the plat 1 foot high. The Utah plants on the same date stood from 2 to 3 inches high in the best spots, the stand being very uneven. The Arabian alfalfa was clipped with the mower at this time and the first irrigation applied to both plats. From this time on the vigorous growth of the Arabian variety was most marked. The Utah alfalfa seemed slow to gather its strength and required the whole summer season for growth before it was high enough to clip with the mower. On the other hand, the Arabian variety after the first clipping and irrigation recovered rapidly and in another month had reached an average height of 10 inches and was again clipped and irrigated. By the middle of September it was ready for the mower again, and this time there was saved from the one-half acre plat 1 ton of green fodder. After this last clipping it revived quickly and went into the winter season with a growth of 8 inches. Eight inches of water was applied to each plat. That this irrigation was the means of producing the splendid growth was plainly evident. The vigorous growth of the young plants of both varieties was maintained throughout the dry season, where without water they would have suffered for moisture just at the time they most required it.

In January a prolonged spell of unusually cold weather was experienced in western Oregon, and in the vicinity of Hillsboro the thermometer dropped to 8° and 10° F. below zero. With no snow to protect the young alfalfa plants, the ground was subject to a heavy freeze which killed out the plat of Arabian alfalfa completely. The Utah alfalfa, on the other hand, although it winterkilled to some extent, withstood the freezing better and came through the winter in much better condition. It is evident from this experience, therefore, that the Arabian variety can not stand cold weather, and, although the temperatures which killed it were very exceptional for this region, it nevertheless would be a poor variety to depend upon unless subsequent investigation shows it to be more hardy as the plants grow older. No effort was made to replant the alfalfa in 1909.

Clover.—The experiment with clover was made on the 8-acre tract that was irrigated by gravity from the mill pond. The results secured from this tract are perhaps the most striking and at the same time the most conclusive of any of the experimental results secured during the investigation. They indicate beyond a doubt the great value of irrigation in the production of leguminous forage crops, and

show that by the application of water during the summer time to such crops as clover the producing value of such land as that experimented upon can be at least doubled at a very slight expenditure of money and labor.

The tract, prior to the time it was planted to clover, had for a number of years been cropped to grain and, like all grain lands of the valley, had a heavy plow sole at a depth of about 6 inches. In the fall of 1906 it was plowed 10 inches deep with an ordinary walking plow, and then subsoiled to an additional depth of 8 inches so as to thoroughly stir the soil and break up the plow sole. After being plowed and harrowed it was seeded to winter vetch and oats on November 24. In February, 1907, red clover was sowed on the vetch and oats. The vetch and oats were cut July 5, and from the appearance of the ground the stand of clover seemed to be very poor, only a few sickly and weak plants appearing. The soil was drying out rapidly, and had there been no opportunity to irrigate the tract it would have been impossible to secure a stand of clover. The tract was given a thorough irrigation as soon as the vetch hay was taken off, with the result that the clover began to grow vigorously. By August 15 it was high enough to cut with the mower, and on that date Mr. Bagley began soiling the crop for the cows. The soiling was continued during the remaining half of August, all of September, all of October, and part of November, and upon more than half the tract a second cutting of clover was secured. As to the yield from the tract in 1907, Mr. Bagley says:

I had no means of securing accurate weights of the crops removed from the tract during the year 1907, but estimated that I secured 20 tons of vetch hay, 100 tons of green clover, 4½ tons of clover hay, and 8 tons of clover silage, and a stand of clover from 6 to 10 inches high which will make excellent mulch. This is the first instance within my knowledge or within the knowledge of any of the farmers of this community that a crop of clover was produced in the year it was seeded; in this instance two crops of clover were produced the year it was seeded, a portion of which was used for silage.

Reducing the estimated yield to an acreage basis, the 1907 crop may be expressed as follows:

Acreage yield of vetch hay and clover under irrigation.

	Tons.
Vetch and oat hay	2.5
Green clover fodder	12.5
Dry clover hay	.5
Clover silage	1.0
Winter mulch, 6 to 10 inches.	

The land was not pastured either in the fall of 1907 or in the spring, as is commonly done in Washington County, with the result that an early spring growth was secured. On May 6 the crop was ready for the mower, and on that date soiling began. The clover was fed to

the milk cows and the hogs as it came from the field, two or three swaths being cut each night and morning for this purpose. By the time the whole field had been cut over in this manner, the clover on the side of the field cut first was ready for the second cutting. The crop was soiled in this way from May 6 to October 10, a period of five months, and during this time four full cuttings in the blossom were taken from the tract. During the first and second cuttings the clover matured faster than the stock could consume it and a part of these cuttings was cured for hay.

The field was irrigated from a gravity ditch out of the mill pond, the same as in 1907. Water was first applied on July 14, the water being used at night mostly, when the mill was not in operation. A second irrigation was given beginning on August 9 and a third beginning September 1. An accurate measurement of the total water applied could not be made, owing to the fluctuation in head available, but an approximate estimate of the water applied would place the total amount at 1 acre-foot per acre. The aggregate time required for each irrigation did not exceed three days.

Based upon actual weight, there were removed from the 8 acres during the five months' cropping season 195 tons of green clover fodder and 7½ tons of dry clover hay. Reducing the green clover yield to a cured hay equivalent, using the ratio of 4 to 1,[a] the total yield of the tract in cured clover hay may be stated as 56.25 tons, which is a yield of 7.03 tons per acre. To emphasize just what this yield means as an argument in favor of irrigation, reference will be made to the yields secured the past season on four of the best cared for clover fields in Washington County. The yields given are based upon statements made by the owners.

Adam Bender.—Area of field, 7.5 acres. Soil well fertilized with manure. Yield, first crop, 3 tons per acre. Yield, second crop, 2.5 acres gave 1 ton of hay per acre; 2.5 acres cut for seed that yielded 325 pounds per acre; the remaining 2.5 acres were pastured.

Herman Kamna.—Area of field, 10 acres. Yield, first crop, 3.5 tons per acre. No second crop was cut, the field being pastured.

Jacob Milne.—Area of field, 60 acres. Yield, first crop, 3.5 tons per acre. No second crop was cut, field being pastured.

F. R. Davis.—Area of field, 80 acres. Yield, first crop, 3 tons per acre. Second crop on 40 acres was cut for seed that yielded 200 pounds per acre. The remaining 40 acres yielded no crop, field being pastured.

It is common practice in raising clover to delay cutting the first crop until after July 4, by which time all danger of damage from rains is usually past. Under this practice it is impossible to secure subse-

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[a] Johnson, How Crops Grow, pp. 39, 40.

quent crops, owing to the dry season coming on and preventing further growth. Some of the more successful growers, by cutting their first crop before July 1, are able to get a small second crop for seed, but the majority usually pasture their clover fields the remainder of the season after the crop is taken off and make no effort to get a further growth. Under existing conditions the three best months in the year—July, August, and September—can not be made use of in the production of hay, for the fields lie practically dormant during this period, waiting for the early fall rains to moisten the soil and revive the growth of the plants. All through the dry summer months, when the clover in other fields stood only 2 to 3 inches high and was parched and brown, the irrigated clover on the Bagley farm maintained its vigor and grew rapidly, piling up its yield until at the end of the season it had produced more clover than any other field of twice its size in the county or in the valley.

Not only was irrigation responsible for this greatly increased yield of clover, but it produced also quite as important a result in providing green fodder throughout the dry season for the dairy herd and other animals on the farm. With the exception of a little chop feed given the dairy herd, this 8-acre tract produced in 1908 the entire food supply for 20 head of milch cows, 60 head of hogs, and 2 horses for the five-month period from May 6 to October 10, and in addition produced 7 tons of dry hay.

RESULTS IN 1909.

Heavy and well distributed local showers occurring during May, June, and during the first week in July postponed the regular droughty period until well along in July. Aside from this, normal conditions prevailed. The crops experimented upon were corn, potatoes, turnips, and clover.

Corn.—Five and one-half acres of corn for ensilage were planted May 20. Poor seed had been secured, so that the stand was very uneven. A good growth was secured, nevertheless, and with favorable weather during May and June a fair stand of corn was obtained. The crop was given but one irrigation, water to a depth of 4 inches being applied August 2 and 3. Another irrigation could have been applied with benefit, but a scarcity of labor prevented.

The corn was cut and put into the silo the first week in October. The total yield of green fodder was 693,000 pounds, which was equivalent to an acreage yield of 12,600 pounds.

Potatoes.—A plat containing three-fourths of an acre was planted to Burbank potatoes on May 12, and a splendid stand secured. Potatoes were given two irrigations, one July 31, when the tubers were about the size of a hen's egg, and another on August 16. A

depth of 6 inches was applied the first irrigation, and a depth of 4 inches was applied at the second. This amount of water, together with the rainfall previously received, seemed to give the best results. The yield from 0.75 acre was 183 bushels of marketable tubers. The yield per acre on this basis was 244 bushels. The potato crop in other parts of the county was extremely light, the tubers being very small, with only a small percentage of good marketable size and quality.

Turnips.—No returns can be given for the turnips, as they are still in the ground at the time this report is being written, it being the practice to feed turnips directly from the field throughout the winter.

Clover.—The experiment on the 8-acre clover tract was continued in 1909. In the production of clover where irrigation is not practiced it is practically impossible to secure paying yields after the second season of bearing. The land becomes so foul with grass and weeds that the clover is crowded out and reseeding is required. This was the third successful bearing season for the 8-acre tract in question, and the results secured, although they were not what they might have been, show most conclusively the benefit to be derived from irrigating clover.

As the land was not pastured in the fall of 1908 or the following spring, an early growth was secured, and the clover was ready to cut by May 1. Soiling was commenced on May 3, and two complete cuttings in the blossom were secured by July 14. One irrigation was applied June 15, when the first crop had been taken off, and another should have been applied about July 15, when the second cutting was completed, but a rainfall of 2 inches on July 4 and 5 revived the crop to such an extent that it was thought the second watering could be dispensed with. That this rainfall was entirely insufficient to meet the needs of the crop was later demonstrated. Instead of growing rapidly after the second cutting was taken off, the clover, while it remained green, made no considerable growth, and as a result the third crop was much delayed. Realizing that a thorough wetting was necessary, the tract was irrigated on August 1. The clover at once began to make a good growth, and by August 22 was ready for the mower, and the third cutting was begun and continued until September 15.

There was taken from the 8 acres during the season of 1909, 145 tons of green clover fodder, and during the first and second cuttings there was an excess that the dairy herd did not consume, that was cured for hay, the weight of which was 6 tons. On a dry-hay basis the yield of the tract was, therefore, 5.3 tons per acre, which was about double the yield secured from clover fields elsewhere that were not irrigated.

The yield of the tract for the season, owing to the delay in the third cutting, was not what it might have been and fell considerably below the yield of 1908. It was, however, much in excess of other clover fields in the county, and as it was the third season in bearing for this tract the results secured were most unusual.

EXPERIMENTS IN COOPERATION WITH COCKERLINE AND HOWARD, NEAR ALBANY, OREG.

The experiments in cooperation with Cockerline and Howard were made upon a 70-acre tract located 1 mile south of Albany, in Linn County, to determine the value of both irrigation and drainage in bringing back to a state of productiveness land which will no longer respond readily to cultivation, owing to the poor physical and chemical condition of the soil resulting from inadequate drainage and long-continued shallow cultivation.

SOILS.

The surface soil, which varies from 18 inches to 2 feet in depth, is a heavy clay loam. The subsoil is a yellow clay. There are two depressions on the tract in which "white land" occurs. This white land, so called because of its color, is the product of bad drainage and results from the continued leaching of gray clay loams. In its natural condition it is very hard to cultivate and practically valueless as crop-producing land. When properly underdrained, however, and given good cultivation, it has been found to take on a darker color and become more loose and friable.

DRAINAGE.

With a view to determining the value of thorough underdrainage on this class of soils, a tile-drainage system was installed by this Office during the winter of 1907 and 1908 to relieve the soil of its excess of water during the rainy season. By thus removing the water as fast as it falls on the land, water logging can be entirely prevented and the soil kept in good condition for early cultivation in the spring. The drains have been in operation but two seasons and their full effect can not yet be determined. Their behavior thus far, however, indicates that they are serving their purpose admirably and that in due time they will aid materially in bringing back to a producing condition land which heretofore had been deteriorating steadily with each season's water logging. Two thousand feet of tile, varying from 3 inches to 10 inches in diameter, were laid on a little more than 60 acres at a cost of approximately $20 per acre.

CULTIVATION.

In the spring of 1908, after the work of laying tile had been finished, the entire area provided with underdrainage was plowed and subsoiled, the land being plowed to a depth of 8 inches with an ordinary walking plow and then subsoiled an additional 8 inches in depth with a subsoiler. This deep cultivation has destroyed the heavy plow sole that existed and put the surface soil into intimate relation with the subsoil, thereby establishing the right conditions for good drainage and proper aeration of the soil.

IRRIGATION.

Through the courtesy of the Willamette Water Company, it is possible to secure water for irrigation by gravity flow from their power canal which flows through the property. Little opportunity has as yet been afforded to determine the value of irrigation as an aid to the growth of forage crops during the dry season for the reason that none of the forage crops planted last season have reached a stage where water can be applied with benefit. Partial experiment the past season has indicated that it is unwise to water field crops on this type of soil until they have reached a stage where they can shade the ground and prevent baking and the plants are vigorous enough to withstand such baking as occurs. The value of irrigation on cultivated crops was demonstrated satisfactorily.

CROPS.

To build up the humus in the soil and to increase the nitrogen content, both of which are very deficient, it was decided that as rapidly as possible the tract should be put into leguminous crops. Seventeen acres on the best naturally drained part of the tract was planted two years ago to alsike clover. It had so nearly run out, however, that after it had produced a crop of seed in 1909 no further growth could be secured by the application of water.

Red clover.—Twenty-three acres were planted to red clover in the spring of 1909. The subsoiling and preparation of the land delayed the planting until June 1, which was so late in the season that no stand was secured. Most of the seed remained in the dry soil during the entire season without germinating. An effort was made to "irrigate the seed up" on a part of the area, but without success. The surface soil ran together and baked and stifled the growth of the young plants. It seems almost certain that on land of this character irrigation will be of benefit only after the crop is in good growing condition and is able to withstand the baking that must always occur where cultivation can not be resorted to or where the crop is not high enough to shade and protect the soil from the sun.

RESULTS IN 1908.

Field peas.—Fourteen acres of the poorest land were planted to Blue Prussian field peas for green manuring purposes. These were planted late also, but a good stand was secured. Owing to the location of the supply ditch, only 4 acres of this area could be irrigated. Water was applied August 3, with the result that a much heavier growth was secured than on the unirrigated area. As all the peas were plowed under for green manure, no estimate of the yield can be given. It seems safe, however, to estimate the increase in green matter due to irrigation at 75 per cent. The peas matured on both the irrigated and unirrigated areas before they were plowed under, and with the aid of the early fall rains gave a second crop, which grew well up to the first of the year, when vetch was seeded with the peas for the coming season's growth.

Cultivated crops.—Eight acres were prepared for furrow and cultivated crops, corn, beans, pumpkins, and potatoes being planted. Like the crops on the other stations, these crops were laid low by the frosts in the latter part of September, and their full development cut short. Partial yields, however, were secured, which are worthy of consideration, especially when it is remembered that the soil upon which they were produced is classed as "worn-out."

But one irrigation was given the cultivated crops, and that began on July 30. Approximately 6 inches of water was applied in this one irrigation. From the behavior of the crops both before and after irrigation, it is evident that the water should have been applied much earlier. Crops in the Willamette Valley do not show the effects of drought as they do in the arid sections, and it is very difficult to determine just when water should be applied.

Corn.—A plat containing 2 acres was planted to field corn on June 6. Both a good stand and a good growth were secured, although a better growth would have resulted had the plat been irrigated earlier, as suggested above. Thorough cultivation was given both before and after irrigation. The total yield of green fodder from the 2 acres was 34,000 pounds, which is equivalent to 17,000 pounds per acre.

Beans.—A plat of 1 acre was planted to small white navy beans on June 8. Of all the crops planted, these showed themselves by vigorous growth the best adapted to present soil conditions. The yield promised to be a heavy one, all pods being well filled. The frosts killed the vines, however, before the beans had an opportunity to ripen, so that no crop was secured. The beneficial effect of irrigation on the beans was most noticeable.

Pumpkins.—One acre was planted to pumpkins on June 8. These, like all other crops, were caught by the frost when only about 60

per cent of the crop had matured. Twenty-five loads, averaging 1,500 pounds per load, were taken from the plat. Five loads, not being matured, were unsalable. The total yield from the 1 acre was 37,500 pounds. Much more than this could have been secured had the immature pumpkins had opportunity to ripen. In the case of this crop the effect of the one irrigation was also very noticeable.

Potatoes.—Two plats of potatoes were planted on June 11. One of the plats, containing 1 acre, was not irrigated; the other, containing 2 acres, was irrigated once in the same manner as the crops already discussed. Frost damaged these also, killing the vines before many of the tubers had reached their full development. From the 1-acre unirrigated plat, 68 bushels of marketable tubers were dug, while the 2-acre irrigated plat produced 231 bushels of marketable tubers. Not only did the irrigated potatoes show this increase of 70 per cent in yield, but the tubers themselves were larger and of a better quality than those from the unirrigated plat.

RESULTS IN 1909.

The failure to secure a stand of clover in 1908 made it impossible to make any experiments with the irrigation of forage crops in 1909. The experiments of 1909 were therefore confined to irrigation of cultivated crops, to the production of which 12 acres were devoted. The crops planted were corn, beans, pumpkins, potatoes, and squash. Two irrigations were applied to all crops except the beans, which were given but one, the experience of the year previous showing that if this crop is given too much water there is an excessive growth of foliage and the ripening of the bean is delayed to such an extent that early fall frosts are apt to cause damage before maturity. Water to a depth of 6 inches was applied at each irrigation.

Corn.—A plat of 1 acre was planted to corn May 16. When the corn was about 4 inches high cutworms destroyed practically the entire stand. A replanting was also destroyed when it had reached about the same stage, so that no crop was secured and no results can be reported for 1909.

Beans.—A plat of 2 acres was planted to white navy beans on May 18. Like the beans planted the previous season, they made a splendid growth and showed their adaptability to the heavy clay soil. They were irrigated once, June 17, 6 inches of water being applied. The crop matured fairly well and was pulled the last week in September, the vines being piled in the field to allow further ripening. Heavy rains just at that time, however, damaged all the beans that were not fully matured and the yield in marketable beans was materially decreased as a consequence. From the 2 acres, 1,250 pounds of marketable beans were thrashed, which, although not a heavy yield, gave a good return from land in such poor condition.

Pumpkins.—One acre was planted to pumpkins May 17. Two irrigations of 6 inches each were applied July 18 and August 4. A good growth and a good yield were secured, the 1-acre plat producing 10 tons of marketable pumpkins, which were sold to dairymen for one-half cent a pound in the field. This is another crop that seems to do very well on the heavy clay soil if given sufficient moisture during the dry season.

Potatoes.—In view of the success of the previous season, 6 acres were planted to potatoes. These were given two irrigations, also, one of 6 inches on June 18 and 19 and one of 6 inches on August 5 and 6. The 6 acres produced 1,014 bushels, which was at the rate of 159 bushels per acre. This is not a heavy yield for potatoes, of course, but when the condition of the soil is taken into account and when it is also considered that potatoes as a general crop throughout the valley in 1909 were largely a failure, the yield secured may be taken as showing the value of irrigation even where the soil is not exactly adapted to it.

Squash.—The plat of 1.5 acres of squash was planted May 16. Two 6-inch irrigations were applied, one on June 23 and one on August 7. These produced even better than the pumpkins, and gave a yield of 12 tons per acre. The value of irrigation on this crop was also most marked, showing that where water is available for irrigation squash can be employed profitably in a scheme of crop rotation designed to bring the worn land back to its original condition.

EXPERIMENTS ON THE HOP YARD OF OSWALD WEST, NEAR CORVALLIS, OREG.

The Willamette Valley produces about one-eighth of the hop crop of the world. This crop is therefore one of the important products of the valley. Production is confined almost entirely to the bottom lands along the river and to sections where the soil is naturally moist.

The yard upon which these experiments were made is located on Kiger's Island, 3 miles south of Corvallis. The soil is a sedimentary deposit of fine silt underlaid by a porous gravelly stratum and dries out to such an extent that the hops, especially those on the higher elevations, suffer from lack of moisture. The equipment for the irrigation of the yard consisted of a 6-horsepower portable engine and a 4-inch centrifugal pump. Water was lifted 25 feet and discharged into a flume 800 feet long, which conveyed it to the yard. The plant was installed about the middle of July, 1907. In reporting the experiment Mr. West says:

> In 1906 the yard produced, without irrigation, about 800 pounds per acre, which is a little less than an average yield for yards in the Willamette Valley; many yards on the river bottoms yield, however, a ton to the acre, and even more. In 1907 less than

one-half of my 25-acre yard was irrigated and only for a period of about fifteen days in July and August. The yard was irrigated from the Willamette River with a 4-inch pump and a 6-horsepower gasoline engine. About 150 gallons of distillate were used for fuel, which cost 11.5 cents per gallon. One man was able to look after the engine and pump and do the ditching, which was done with a plow. The yield from the entire yard averaged 1,150 pounds per acre, which would mean about 80 per cent increase as the crop on the unirrigated part of the yard was about the same as it was the preceding year, except that portions of it may have derived benefit through subirrigation, which might have increased the yield.

The results have shown that irrigation can be carried on successfully in the Willamette Valley, and on places situated similar to mine can be conducted at very little cost; also that the yield can be increased at least from 75 per cent to 100 per cent. I hope eventually to have the whole place, 150 acres, under irrigation.

The experiments were continued in 1908, one-half of the yard, 12½ acres, being irrigated. The remaining half was not watered, because the plant did not have sufficient capacity to supply the entire 25 acres. Water was applied August 1 to 10, but no record was kept of the amount applied. When the crop was picked, the 12½ acres not irrigated gave a yield of 750 pounds per acre, while the 12½ acres that were irrigated gave a yield of 1,500 pounds per acre, showing an increase in yield due to irrigation of 100 per cent.

This experiment shows that irrigation can be used to great advantage in the production of hops, especially where the yard is located on upland or on porous gravelly bottom land. It serves not only as valuable crop insurance during seasons of scanty rainfall, but greatly increases the normal production.

EXPERIMENTS ON THE MARKET GARDEN OF ROBERT GALLATLY, NEAR PHILOMATH, OREG.

The purpose of the experiment on the market garden of Robert Gallatly, near Philomath, was to determine the value of irrigation in the production of onions. For market gardens and for the raising of vegetables in general, irrigation is without doubt of great value. This has already been demonstrated in the market gardens throughout the valley. To produce the first crop of vegetables, especially the early-maturing varieties, irrigation is not necessary if sufficient cultivation is given. For a second and later crop of vegetables, however, and for such slow-growing crops as celery and cauliflower, irrigation eliminates all possibility of damage from drought and produces, even in average seasons, better results than are secured by dependence upon natural rainfall.

Mr. Gallatly has for a number of years raised vegetables under irrigation. The 2-acre tract devoted to the experiment is a rich creek-bottom loam which absorbs water readily. Water is obtained from a small creek by gravity flow and the amount applied to the onions experimented upon was measured over a weir. In making the test

it was arranged to leave a part of the onion patch unirrigated, twenty-four rows, each 60 feet in length, being set apart for this purpose. The entire patch included an area of 10,000 square feet. The rows were spaced 1 foot apart and water was applied to each row from a head ditch. The crop was given four irrigations during the season, water being applied as follows.

Depth of water applied to onions at Philomath, Oreg.

	Feet.
First irrigation	0.79
Second irrigation, June 20–22	1.23
Third irrigation, July 12	.73
Fourth irrigation, July 23–26	.76
Total for season	3.51

In irrigating, much more water was applied than was absorbed by the soil, the excess passing off to other parts of the garden and also wasting into the creek. There was no way of determining the amount of this excess, but it is safe to assume that three-fourths of the amount applied passed off as waste.

The 24 rows that were not irrigated showed a marked contrast to the irrigated rows by the time the second watering was given. These rows did not have the color or the size of the irrigated rows and clearly showed the need of moisture. It was not possible to do away entirely with subirrigation on the unirrigated rows, but the difference in yield between the irrigated and unirrigated onions very clearly indicated the value of irrigation when the moisture in the soil is deficient. When the onions were harvested, 24 representative rows were selected from the irrigated area for comparison with the 24 unirrigated rows.

The results were as follows:

Yield of irrigated and unirrigated onions, Philomath, Oreg.

	Pounds.
Yield from 24 irrigated rows	850
Yield from 24 unirrigated rows	350
Increase	500

On an acreage basis, the yield was as follows:

	Pounds.
Yield per acre, irrigated	25,700
Yield per acre, unirrigated	10,587
Increase	15,113

Not only was there this increase in yield, but there was a marked difference in both size and quality in favor of the irrigated onions. The patch, less than one-fourth acre, yielded 150 bushels of onions.

SUMMARY.

The results of the several experiments of the past three seasons are brought together in the following summary. It has not been possible in all cases to compare the yields of the irrigated areas with those of the unirrigated areas. In a number of cases, however, such a comparison is possible, and in these the effect of irrigation is strikingly brought out.

Summary of results from irrigation experiments in Willamette Valley, 1907–1909.

Experimental tract.	Season.	Crop.	Yield.		Increase.
			Unirrigated.	Irrigated.	
			Per acre.	*Per acre.*	*Per cent.*
State experiment station	1907	Corn (green fodder) pounds	5,647	9,666	71
Do	1908	Corn (green fodder) do	7,280	a 9,640	32
Do	1909	Corn (green fodder) do	11,125	14,153	36
Do	1909	Corn (sweet corn) do	7,000	13,750	96
Bagley farm	1908	Corn (green fodder) do		a 18,000	
Do	1909	Corn do		12,600	
Cockerline and Howard farm	1908	Corn do		a 17,000	
State experiment station	1907	Potatoes bushels	43	125	180
Do	1908	Potatoes do	60	a 86	39
Do	1909	Potatoes do	150	215	43
Bagley farm	1909	Potatoes do		244	
Cockerline and Howard farm	1908	Potatoes do	68	a 115	70
Do	1909	Potatoes do		169	
State experiment station	1908	Beets (red) pounds	2,725	4,309	58
Bagley farm	1908	Beets (mangels) do		24,000	
Gellatly farm	1907	Onions do	10,590	25,700	143
Cockerline and Howard farm	1908	Pumpkins do		a 37,500	
Do	1909	Pumpkins do		20,000	
Do	1909	Squash do		24,000	
Do	1909	Beans (small white navy) do		625	
West hop yard	1907	Hops do	640	1,150	80
Do	1908	Hops do	750	1,500	100
State experiment station	1908	Red clover hay tons	5.07	b 6.46	27
Bagley farm	1907	Red clover hay do	c 3.00	4.70	57
Do	1908	Red clover hay do	c 3.50	7.03	101
Do	1909	Red clover hay do	c 2.50	5.30	112
Do	1908	Kale do		30	

a Damaged by frost.
b Water not applied early enough, owing to breakdown of pumping plant.
c Yield of representative neighboring fields.

CONCLUSIONS.

The investigations and experiments that have been made have brought out certain facts and warrant certain conclusions, as follows:

IRRIGATION NECESSARY.

The experiments made, though incomplete in many respects, have shown conclusively that great benefit is to be derived from summer irrigation in the Willamette Valley; that through it crops may take advantage of the best growing months of the year, thereby giving not only a more assured return but a greatly increased yield; that without irrigation crops must depend upon the natural rainfall, which is uncertain, and at the best is insufficient in amount to maintain proper soil-moisture conditions.

ALL CROPS BENEFITED BY IRRIGATION.

The benefits of irrigation seem to be confined to no one crop. All crops experimented upon—corn, potatoes, beets, clover, alfalfa, kale, beans, onions, hops, pumpkins, and squash—show a decided increase in yield, also improvement in quality when irrigated. The smallest increase secured from any one crop was over 30 per cent, and in this case the crop was damaged by frost before maturity. The largest increase was nearly 180 per cent. In general, it seems safe to say that the intelligent application of water to crops will easily increase yields from 75 to 150 per cent. In other words, irrigation properly applied will double the output of farming operations.

IRRIGATION OF FORAGE CROPS.

The growing importance of the dairy industry in the Willamette Valley is fast bringing the production of forage crops to be one of the most important phases of farm practice. The climatic conditions during the growing period of these crops are such as to make the fullest development difficult. Owing to the mild, moist spring, most hay crops, if permitted to grow, are ready for cutting toward the first of June, but as a rule a rainy period may be expected about that time, and unless the time of curing be delayed the hay crop is very apt to be damaged while curing. To prevent this and to delay the haying season until more settled weather can be counted upon, the practice of pasturing the crop in its early stages of growth, in March, April, and May, has become quite common. By so doing, however, the growth of a possible second crop is delayed and the dry summer period comes on before the plants can make much headway toward a second crop. As a result, only one good crop of hay is secured, with possibly one light crop following, which is either cut for hay or allowed to produce seed.

Another effect of the dry summer season is to deprive the dairy herd of green food during the very months of the year when it should be the most abundant. Through the balance of the year, by judicious selection of soiling crops, dairy cows can be provided with green food. In the summer time when the pastures are all dried up they must subsist on dry hay and silage. One of the greatest benefits to be derived from irrigation will therefore be in the production of forage crops.

The Hillsboro experiments have shown conclusively that in the case of red clover the yield can easily be increased 100 per cent, and not only is it thus possible to increase the productiveness of the land, but the dairy herd can be provided with green fodder throughout the dry summer by soiling the crop, thus solving one of the most serious problems confronting the dairymen at the present time.

IRRIGATION OF POTATOES.

The benefit of irrigation to potatoes seems to be quite well demonstrated. A question yet to be solved in connection with late-planted potatoes is whether it is best to irrigate before planting or after. The potatoes raised thus far which have been irrigated after planting have shown a slight tendency to be rough coated and subject to second growth unless the water is applied at the right time. As all the potatoes raised were produced on rather heavy land, it is thought this trouble may be due to the heavy soils running together and hindering the proper development of the tuber. One experiment was tried in 1908 in which the soil was irrigated, then plowed and seeded, and no more water given to the crop. The crop was planted the second week in July. The tubers showed neither of the troubles mentioned, and promised a heavy yield up to the time the frost killed the vines and stopped their growth. Just what is the best method of irrigating late planted potatoes remains for future investigation.

IRRIGATION OF CORN.

Irrigation almost doubles the yield of corn fodder. The production of corn fodder, however, is not an important item, since there are other and better forage crops that can be raised. What is needed is a variety of corn that can be ripened successfully under Willamette Valley conditions, the grain to be used for finishing purposes in connection with the production of hogs and beef. The State Experiment Station is now breeding up such a strain of corn, and if these efforts are successful an important problem connected with stock feeding will have been solved. The value of irrigation in the production of ripe corn remains to be determined.

IRRIGATION OF ROOT CROPS.

Root crops can be immensely benefited by irrigation, and as these will form an important part of the production and feeding ration on the diversified farm the value of irrigation in their production can be readily appreciated.

DEEP PLOWING AND SUBSOILING.

There can be no question as to the benefit of deep plowing and subsoiling, especially on land that has been cropped to grain for any length of time. Wherever a heavy resistant plow sole exists subsoiling should be resorted to in order to put the soil in shape for good cultivation. So long as the surface soil remains isolated from the subsoil by such an impervious barrier the producing power of the soil will be limited. Such a loosening of the soil is absolutely essential where irrigation is to be employed, in order that the water applied may percolate properly into the subsoil.

EFFECT OF WATER ON SOILS.

There seems to be a fear on the part of some that irrigation will have a damaging effect on the soil. Their contention is that inasmuch as the soil is saturated during a large part of the year from the heavy rains the tendency to saturate them during the summer under irrigation will give them no chance to "dry out" during the summer season and they will become "sour" and lifeless. This idea is founded on a misconception of what irrigation really means. Land that is intelligently irrigated is not saturated. But on the other hand, just enough water is applied to maintain the proper moisture conditions. Where such a practice is followed no harm can possibly be done to the soil, for with proper drainage the aeration of the soil is in no way interfered with, and so long as this condition is maintained the soil will not become "sour" or lifeless. It is admitted that much damage can be done through ignorance or carelessness on the part of an irrigator or where poor drainage conditions exist, but with careful handling of the water no harmful results need ensue.

EFFECT OF IRRIGATION ON CROPS.

Much the same can be said of the effect of irrigation on crops as has just been said of its effect on the soil. Too much water will damage the crop; this is especially true of fruits. Careful experiment, backed up by the opinions of those who have had much experience in irrigation, proves the fallacy of the contention that crops raised with irrigation are inferior to those raised without it. As in all other farming operations, much depends upon the irrigator himself. If he is careful and painstaking in his work and is guided by a careful study of the conditions that prevail, the results he will accomplish will demonstrate to him that irrigation is but a means of improving natural conditions and that where intelligence and care are used no harmful effects will result to either soil or crop.

WHEN WATER SHOULD BE APPLIED.

Crops in the Willamette Valley do not show the effects of drought, as they do in the arid regions where the evaporation is excessive, and it is a difficult thing to determine just when water should be applied to produce the best results. With the atmosphere never excessively dry, enough moisture, especially in the form of dew, seems to be present to prevent crops wilting or turning color, and instead of showing plainly the need of moisture, as they do in dry climates, their growth seems to be simply suspended until the soil receives water from some source. Under such circumstances, the needs of the plant must be anticipated in the matter of irrigating it and the condition of the soil should be taken as a guide rather than the condition of the

plant. The effect of delaying irrigation was well illustrated by the behavior of the Bagley clover tract in 1909. It was thought that the heavy rainfall early in July would make a second irrigation unnecessary at that time. No water was applied, and as a result the clover practically stood still in its growth, the rainfall received simply offsetting the evaporation. The crop remained green, but made no growth until water was applied.

In general, it seems that irrigation should begin in average years not later than July 1 and regular applications should be made throughout the dry period without reference to showers, which seldom prove to be of material benefit. Cultivated crops, it seems, should have not less than two irrigations, while hay crops will require more.

AMOUNT OF WATER REQUIRED.

It has been impossible to determine with any finality the exact amount of water that should be applied. Measurements that have been made indicate that the average duty of water for all farm crops will approximate 1 acre-foot per acre on the field, the water being applied in two or three irrigations of 4 to 6 inches each. This, of course, would be the duty of water on the field, losses in transit from the source of supply not being taken into account.

IRRIGATION OF FRUIT.

No experiments have been made to determine the value of irrigation in fruit culture in the Willamette Valley, because it has been impossible to secure a tract in bearing fruit conveniently located with respect to a suitable water supply on which the use of water in irrigation might be tried. With the scarcity of rainfall, however, it seems not unreasonable to expect that even the orchard and berry patch will benefit greatly under irrigation except in cases where they are already located so as to be provided with natural subirrigation. The value of irrigation has already been demonstrated beyond question in the orchards of the Rogue River Valley, for the orchards there that are producing the heaviest and yielding the largest profits are irrigated, almost without exception. The belief that orchards in general will be benefited by intelligent irrigation seems to be well founded.

FEASIBILITY OF IRRIGATION IN WESTERN OREGON.

With the need of irrigation in western Oregon during the dry summer months conclusively proven, and with the great value of irrigation as determined by actual experiment fully demonstrated, the question arising next is the feasibility and practicability of irri-

gation development on an extended scale. Analyzing first the water supply of the region, a complete network of streams is found making its way into the valleys from both the Cascades on the east and from the Coast Range on the west. The Willamette and its tributaries, the Umpqua and its tributaries, and the Rogue River and its tributaries discharge enough water annually to cover the arable land in their respective valleys many feet in depth. It is a fact, of course, that much of this water comes at a season when it can not be made use of and that during the summer months when the greatest demand will occur the stream flow is at its lowest stage. Many of the streams, however, have a strong summer flow and this flow, where existing rights do not interfere, is available for direct diversion. Where existing rights do interfere or where the summer flow is inadequate, storage in the majority of cases can be easily and cheaply provided. There are many natural storage sites in both ranges of mountains that are capable of economical development, and already some of the more favorable ones are being developed against the time when reliance will be placed upon them to supplement the normal flow of the streams in the summer time. Fish Lake and Four Mile Lake in the Rogue River basin, for instance, are now being developed as natural storage reservoirs to be used in connection with the Rogue River Reservoir, Irrigation, and Power Company's project that is being constructed to supply the upper Rogue River Valley with irrigation water. The combined storage capacity of these two lakes is 35,000 acre-feet. Another natural lake that is being developed as a storage reservoir is Waldo Lake, on the headwaters of the Willamette River. The storage capacity of this lake when fully developed will approximate 150,000 acre-feet. Many other smaller lakes in the several drainage basins can be utilized at small expense and also many natural reservoir sites can be developed by the construction of dams, all of which can be made to supplement the normal summer flow of the streams. With such a condition existing in the matter of a water supply it can be safely said that water in abundance is available for the most extensive irrigation development.

The problem of bringing the water onto large tracts of land is comparatively a simple one in most cases, the general topography of the region being such as to eliminate long and expensive diversion canals. Especially is this the case in the Willamette Valley, where practically all of the streams emerge from the mountains on a heavy grade and where the land to be irrigated is extremely smooth, with light grades. In this valley alone many projects are capable of development where the acreage that can be controlled varies from 5,000 acres to 50,000 acres and where the actual cost of putting the water on the land will vary from $10 to $30 per acre, which is a low acreage

cost in comparison with that required in many other sections where projects have been and are now being successfully built. Speaking generally, it may be said that canal construction in the region studied will be no more expensive and involve no more difficulties than in other irrigated sections of the West; and that in particular cases, especially in the Willamette Valley, projects of 5,000 to 25,000 acres are so favorably located that the cost of their complete development will not exceed $12 or $15 per acre.

As to the ultimate effect of irrigation on the various types of soils it can be positively asserted that with the possible exception of the "white lands" of the Willamette Valley there is not a single type of soil from the extremely porous gravelly soils to the fine textured alluvial bottom lands that will not be greatly benefited by cultivation under irrigation. In the case of the "white land" irrigation will not injure it, but in its present run-down condition irrigation can be used but to slight advantage until such time as it has been brought back to a fair physical and chemical condition by intelligent crop rotation, fertilization, and underdrainage. It is the erroneous impression of a few that irrigation will sour the soil; that is, water-log it to such an extent as to prevent complete aeration and cause it to become lifeless and inert. It is contended that the soil is so thoroughly saturated by the heavy rainfall during the winter that the dry summer period is necessary to drain the soil and dry it out thoroughly before the next rainy season comes on, and that if the soil is irrigated during the dry summer it will have no opportunity to "dry out" and will "sour." Those who reach such a conclusion overlook the fact that these same soils have for hundreds of years assimilated with no ill effect a rainfall of from 30 to 40 inches each year and in doing so have developed a natural system of surface drainage and underdrainage that is entirely capable of disposing of the small amount of extra water that will be applied in irrigation. They fail also to comprehend the real purpose or method of irrigating the soil, for it is not the purpose to saturate or water-log the soil, but simply to maintain the moisture conditions necessary for good crop growth during the time when the soils would otherwise be too dry. Such a use of water on any soil can result only in benefit and no damage need be feared.

With an abundant water supply assured, with the general topography of the region such as to especially favor the cheap and economical delivery of the water on the land, and with the soils themselves adapted to irrigation, no reason is apparent why irrigation development is not feasible and practicable.

THE PART IRRIGATION WILL PLAY IN THE AGRICULTURAL DEVELOPMENT OF WESTERN OREGON.

As the result of a widespread campaign of education and advertisement, western Oregon is experiencing to-day one of the greatest eras of growth and development it has ever known. From all over the Union men are coming to this region to locate and invest their capital. Along commercial and industrial lines the development is very great indeed. Along agricultural lines there is much investment and speculation, but on the whole, little real development is taking place outside of a very few especially favored localities. This backwardness in the actual development of the agricultural industry constitutes one of the most serious economic problems confronting western Oregon. This region is essentially and preeminently an agricultural one, and the chief supporting industry will always be agriculture; yet substantial development along this line is falling far behind the development along commercial and industrial lines, and as a result an abnormal condition is rapidly being created. The cities and towns are growing rapidly, their population is increasing, but the farming industry that is to support this growth of the cities and towns is making slow progress. Outside of the favored districts that are progressing, the general farming area is clinging to the same methods and securing the same results that obtained fifteen and twenty years ago. In the heart of the large farming area, the large 320 and 640 acre farm is the rule, and the raising of grain crops that do not yield 2 per cent net return on the assessed valuation of the land is tenaciously adhered to. Land values are rising, it is true, but in the main this increase is a sympathetic and speculative one and is not based on the increased productiveness of the farm. That conditions are abnormal is proven forcibly by the fact that although it is essentially an agricultural region, the farm products of western Oregon, despite the high prices prevailing, fail absolutely to supply even the local demand. The valleys of western Oregon each year actually import from eastern States and from other outside sections, hundreds of thousands of dollars worth of ham, bacon, lard, butter, canned goods, eggs, and even hay and grain—products that should be grown in such abundance as not only to meet the local demand, but to supply an extensive export trade that waits only to be developed. With such conditions existing, it can readily be seen that normal and substantial development can not take place until such time as the agricultural industry receives an impetus that will enable it to keep pace with the development along other lines.

The reasons for this state of affairs are not difficult to locate. One of the principal reasons for the prevailing condition is that the destructive cultural methods that have been followed for half a century

have so affected the producing power of the soils that they can no longer be farmed with profit in the old manner even though earnest and consistent effort be put forth by the farmer. The soils will not respond as they once did nor can they be made to produce as they should until radical changes in methods are adopted. Another reason is that prevailing farming practice is in a rut. In the majority of cases, not only the farm lands but the farming methods have come down to the present owners as a heritage and the younger generation simply follow in the steps of the older generation which founded the industry, rather than change to the new methods that are absolutely demanded by the radical change in conditions that has taken place. They adopt improvements and innovations slowly, and cling to the methods of twenty years ago that no longer produce remunerative results. For this condition the farmers themselves are largely responsible. The most important reason of all, however, why development should be so slow is that in this necessary change from the old one-crop method to the intensified and diversified method of constructive farming, adverse climatic conditions are encountered that affect most seriously the results that should be secured under the new order of things. In the production of wheat, the dry weather in summer operated only to increase and insure the yield. Grain, however, is but a minor crop where diversified farming is practiced. Hay, fodder, root crops, vegetables, and fruit all enter into the scheme of intensive farming and these crops, growing as they do throughout the entire summer season, are at the mercy of the droughts and suffer according to their severity. Were these summer droughts of short duration or of infrequent occurrence, diversified agriculture would have had a normal development and the problem that exists would not have arisen, but they come as regularly as the seasons and the dry summers with their less than one-quarter of an inch of rainfall in sixty to seventy days in the hot summer are as much a part of the regular climatic cycle as are the heavy rains of December, January, and February. This droughty condition of each summer is the real reason why agricultural development has been so backward in western Oregon, and one of the main reasons why the old methods of years gone by have been adhered to so tenaciously. Some development is of course taking place throughout the region and certain sections that are favorably situated are being intensively developed, but agricultural practice in general is changing but slowly and but little progress is being made in the solution of the main problem.

With the summer droughts and their effects acting as the main obstacle to a normal development of the farming industry, there can be no doubt that the effect of the general adoption of irrigation will be to solve almost completely the agricultural problem that exists.

Through the application of water to crops when they are in need of moisture, methods and practices will change rapidly and farming operations will adapt themselves to the new condition without hindrance or check.

That the adoption of irrigation generally will produce these results may be most confidently expected. The cooperative experiments conducted by this Office as well as the results secured by individuals during the last three years demonstrate beyond question what can be done with irrigation. Not only can crop yields be absolutely assured, but they can be greatly increased, in some cases doubled and trebled at an expense that is trifling when compared with the increased returns secured.

Irrigation will make possible the small diversified farm of 20 to 40 acres, on which a far better living will be made than is now possible on the average farm of ten times that size. No longer will it be necessary to ship packed eggs from Kansas that sell in the local markets now for 30 and 40 cents per dozen. Eastern bacon at 25 to 27 cents per pound and eastern hams at 15 to 20 cents per pound will no longer be called upon to supply the local demand. No longer will eastern Oregon hay at $18 to $20 per ton have to be shipped to western Oregon cities and towns, nor will millstuffs at $25 and $30 per ton have to be fed by the dairyman to his herd to maintain the milk flow in the summer time. The relation of supply and demand will become adjusted, abnormal conditions will disappear, and all through the medium of the small diversified farm which is irrigated.

It will require time, of course for the adoption of irrigation to become general. It is an innovation and it is only natural that at first it should be taken up slowly, especially by those who in the past have placed their dependence upon the natural rainfall and are naturally predjudiced against any plan that "goes against Nature." But the irrigation idea will prevail and eventually the time will come when the farm that is not provided with at least a partial water supply as its insurance policy will be an exception. When that time comes, agriculture in the valleys of western Oregon will be placed upon a sound and permanent basis, and the development of the farm will assume its rightful place in the economic development of the region as a whole.

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